PROGRAM MANUAL FOR HILTOP

A Heliocentric Interplanetary Low Thrust Trajectory Optimization Program

Part I - User's Guide

(NASA-CR-143894) PROGRAM MANUAL FOR HILTOP, A HELIOCENTRIC INTERPLANETARY LOW THRUST TRAJECTORY OPTIMIZATION PROGRAM. PART 1: USER'S GUIDE (Analytical Mechanics Associates, Inc.) 287 p HC $6.75 CSCL 22A G3/13

N75-28084

Unclas 29198

F. I. Mann
J. L. Horsewood

Report No. 74-34
Contract NAS8-29945
December 1974

ANALYTICAL MECHANICS ASSOCIATES, INC.

Page Intentionally Left Blank

SUMMARY

This report describes a Phase A performance-analysis computer program, HILTOP, that has been developed explicitly to generate optimum electric propulsion trajectory data for missions of interest in the exploration of the solar system. HILTOP is a double-precision, FORTRAN IV, IBM 360 production program which is primarily designed to evaluate the performance capabilities of electric propulsion systems and which may, in the hands of a skilled analyst, perform efficiently in the simulation of a wide variety of interplanetary missions. HILTOP uses numerical integration of the two-body, three-dimensional equations of motion and the Euler-Lagrange equations. It contains transversality conditions which permit the rapid generation of converged maximum-payload trajectory data, and allows the optimization of numerous other performance indices for which no transversality conditions are included. In addition to optimizing the thrust direction and on-off switch times, other significant performance parameters that can be optimized are jet exhaust speed, power level, hyperbolic excess speeds, launch asymptote geocentric declination, flight time and launch date. The ability to simulate constrained optimum solutions, including trajectories having specified propulsion time and constant thrust cone angle, are also optionally available. The program is designed to handle multiple-target missions with various types of encounters, such as rendezvous, stopover, orbital capture, and flyby. Performance requirements for a variety of launch vehicles may be determined. The documentation includes problem formulation, program usage specifications, sample problems, and detailed subroutine descriptions.

Page Intentionally Left Blank

TABLE OF CONTENTS

VI. Subroutine Descriptions (cont)

VI. Subroutine Descriptions (cont)

NOMENCLATURE

Generally, upper-case symbols denote vectors and lower-case symbols denote scalars. Lower-case symbols with bars denote unit vectors. The abbreviations EPS for electric propulsion system and BVP for boundary value problem are used.

a	EPS instantaneous thrust acceleration; semi-major axis
a_c	Semi-major axis of primary-target capture orbit
a_i	Solar power law coefficients
$\bar{a}_1$, $\bar{a}_2$	Arbitrary unit vectors used in (132) and (139)
b	A coefficient in the efficiency law
b_1, b_2, b_3	Launch vehicle coefficients
C	Vector constant of optimal rocket problem, expression (63)
C^o	Radians-to-degrees conversion factor
c	EPS jet exhaust speed (constant); abbreviation for cosine function
c_r	Retro stage jet exhaust speed
c_1	Auxiliary quantity given by expression (74)
c_1, c_2, c_3	Coefficients in quadratic expression for Δv_i, expression (78).
d	A coefficient in the efficiency law; an auziliary quantity in the coast-phase solution; solar flux density
E	Eccentric anomaly (a scalar)

e	A coefficient in the efficiency law; the base of the natural logarithms; eccentricity; subscript denoting Earth
$\bar{e}_h$	Spacecraft unit angular momentum vector
$\bar{e}_r$	Spacecraft unit radius vector
$\bar{e}_t$	EPS unit thrust vector
$\bar{e}_v$	Spacecraft unit velocity vector
e_x	Retro stage characteristic speed exponential factor given by expression (76)
$\bar{e}_\lambda$	Unit primer vector
F	Auxiliary scalar function defined by (215)
f	EPS instantaneous thrust magnitude; f-function of the f and g series; subscript denoting a desired value; true anomaly; auxiliary variable defined by equation (147)
f_r	Retro stage thrust magnitude
f_x	Auxiliary quantity given by expression (77)
G_i	Auxiliary scalar functions in the coast-phase solution, equation (45)
g	EPS reference thrust acceleration; g-function of the f and g series; BVP point-constraint geometric mean of the weighting factors
g_x	Auxiliary quantity given by expression (97)
H	Spacecraft angular momentum vector
h	Magnitude of spacecraft angular momentum vector
$\bar{h}$	Spacecraft unit angular momentum vector
h_v	Variational Hamiltonian
h_x, h_y, h_z	Cartesian components of spacecraft angular momentum vector

h_σ Thrust-switching step-function

i Subscript pertaining to an intermediate target; inclination to ecliptic; general subscript or running index; inclination of parking orbit about Earth

$\bar{i}$ Unit vector along x-axis

i_{max} Parking orbit inclination associated with range safety limit

J Index-set of the BVP dependent variables

$\bar{j}$ Unit vector along y-axis

j_p Unspecified-reference-power indicator

j_{ps} EPS propulsion system jettison indicator (retro maneuver)

j_r Retro stage existence indicator

j_t EPS tankage jettison indicator (retro maneuver)

k Arbitrary positive constant associated with performance index; temporary variable ultimately equated to inverse of the characteristic degradation time

$\bar{k}$ Unit vector along z-axis

k_c Auxiliary quantity given by expression (75)

k_{drop} Intermediate-target drop-mass factor defined by expression (6)

k_{rt} Retro stage tankage mass factor defined by expression (11)

k_s EPS structure mass factor defined by expression (8)

k_{samp} Intermediate-target sample-mass factor defined by expression (6)

k_t EPS tankage mass factor defined by expression (7)

L Launch site latitude (scalar)

M Mean anomaly (scalar)

M_0, M_1, M_2, M_3, M_4, M_5	Coefficients used in computing nuclear and total magnitudes of a celestial body (scalars)
M_N	Nuclear magnitude (scalar)
M_T	Total magnitude (scalar)
m	Spacecraft total mass variable
$\bar{m}$	Auxiliary unit vector given by expression (32)
m_{drop}	Intermediate-target drop-mass given by expression (6)
m_{net}	Net spacecraft mass
m_o	Initial spacecraft mass (payload of launch vehicle) given by expression (2)
m_p	EPS propellant mass
m_{ps}	Electric propulsion system mass given by expression (4)
m_r	Retro stage mass
m_{rp}	Retro stage propellant mass given by expression (9)
m_{rs}	Retro stage structure mass defined by expression (11)
m_{rst}	Retro stage structure and tankage mass given by expression (11)
m_s	EPS structure mass
m_{samp}	Intermediate-target sample-mass given by expression (6)
m_t	EPS tankage mass
Δm_p	Propellant mass increment due to primary-target spiral maneuver
n	Exponent in step-size law, expression (39); subscript denoting time at the primary target; number of BVP dependent variables

$\bar{n}$	Unit vector normal to the solar arrays
$\bar{n}_p$	Unit vector directed along a planet's north pole
o	Subscript denoting launch time; subscript denoting the beginning of a computation step
P	A celestial body's position vector; BVP partial derivative matrix
p	EPS instantaneous power; subscript denoting a perturbed, or neighboring, parameter; auxiliary variable in equations (79)
Δp	Ratio of housekeeping to reference power, p_h/p_{ref}
p_a	Total instantaneous power developed by arrays
p_h	Housekeeping power
p_{ref}	EPS reference power
p_1, p_2	Auxiliary quantities in coast-phase solution, expressions (54) and (55)
q	Auxiliary variable in equations (79); solar array radiation damage factor
R	Spacecraft position vector
r	Magnitude of R
r_a	Primary-target capture-orbit apocenter distance
r_c	Earth-to-spacecraft communication distance
$\bar{r}_n$	Unit vector along line of ascending node
r_p	Primary-target capture-orbit pericenter distance; primary-target swingby passage-distance
$\bar{r}_p$	Swingby passage-distance unit vector
r_{peak}	Value of r for which γ-curve is at a maximum
s	Abbreviation for sine function; auxiliary variable used in equations (79); degradation time

$\bar{s}$ Unit vector directed toward Canopus

t Time

t_b Retro maneuver burn time given by expression (12)

Δt Time-increment due to primary-target spiral maneuver

u Generalized universal anomaly during thrust phases

Δu Generalized universal anomaly increment, equivalent to the computation step-size during numerical integration

v Magnitude of spacecraft velocity

v_c Characteristic speed of a rocket maneuver

v_e Escape speed from launch parking orbit

v_g Minimum velocity impulse required for non-coplanar injection from a circular orbit to a given excess velocity

v_o Speed of a spacecraft in a circular orbit

v_p Planetocentric speed at primary-target swingby closest-approach point; auxiliary speed given by equation (72)

V_∞ Hyperbolic excess velocity (or encounter velocity)

$V_{\infty A}$ Swingby planet arrival hyperbolic excess velocity

$V_{\infty D}$ Swingby planet departure hyperbolic excess velocity

v_∞ Hyperbolic excess speed (or encounter speed)

Δv Retro stage impulsive velocity increment magnitude; characteristic velocity associated with primary-target spiral maneuver; incremental speed required at powered swingby

$\Delta v'$ Retro stage total velocity increment magnitude

Δv_o Minimum incremental velocity (magnitude) for coplanar boost out of circular orbit

Δv_g Velocity penalty due to noncoplanar boost out of circular orbit

Δv_i	Velocity penalty due to launch azimuth
w	Auxiliary variable in equations (79)
x	First Cartesian component of position; a general variable; a general state variable; auxiliary variable in equations (79)
y	Second Cartesian component of position; auxiliary variable in equations (79)
z	Third Cartesian component of position
α	EPS specific mass; geocentric right ascension of launch excess velocity
α_A, α_D	Auxiliary parameters defined by equations (211) and (212)
α_a	Specific mass of the solar arrays
α_c	Communication angle (Sun-Earth-spacecraft)
α_t	Specific mass of the power conditioning and thruster subsystem
α_1, α_2	Arbitrary, independent angles defining orientation of excess velocity in (132) and (139)
β	Independent variable of coast-phase solution, also generalized to be the independent variable on the entire trajectory
β_o	Value of β at the beginning of a computation step
$\Delta\beta$	Computation step size (increment of trajectory independent variable)
γ	Normalized power function
γ'	$\partial\gamma/\partial r$
γ^*	$\partial\gamma/\partial d$, where d is the solar flux density
δ	Launch hyperbolic-excess-velocity asymptote declination; BVP dependent-variable tolerance
δ_A, δ_D	Bend angles of hyperbolic arrival and departure trajectories, expression (213)

δ_T	Total bend angle given by expression (214)
δ_{ij}	Kronecker delta function
ϵ	Auxiliary quantity in the coast-phase solution; obliquity of the Earth's equator to the ecliptic
η	EPS efficiency
η'	$d\eta/dc$
θ	In-plane thrust angle
θ_i	Travel angle increment
θ_t	Travel angle
Λ	Primer vector (adjoint to spacecraft velocity)
λ	Magnitude of Λ; a general adjoint variable; the iterator inhibitor
λ_c	Adjoint variable associated with jet exhaust speed
λ_g	Adjoint variable associated with reference thrust acceleration
λ_s	Adjoint variable associated with degradation time
λ_x	Thrust cone angle Lagrange multiplier
λ_ν	Adjoint variable associated with mass ratio
λ_τ	Adjoint variable associated with propulsion time
λ_ϕ	Adjoint variable associated with thrust cone angle
μ	Gravitational constant of the sun; a general gravitational constant
μ_t	Gravitational constant of the primary target
ν	Mass ratio
$\Delta\nu$	Mass ratio increment at an intermediate target
π	Performance index; ratio of circle circumference to diameter
π_x	Partial derivative of π with respect to arbitrary variable x.

ρ Auxiliary variable used in equations (79)

σ Thrust switch function

σ^* Special form of thrust switch function, given by equation (186)

σ_r Portion of total thrust switch function, given by (193)

$\Delta\sigma$ Propulsion-corner-proximity tolerance-interval

τ EPS propulsion time

τ_d Characteristic degradation time

Φ Transformation matrix for rotating from ecliptic to equatorial coordinate system

ϕ Thrust cone angle (between thrust and radius)

χ Angle between normal to solar arrays and the spacecraft-sunline

ψ Out-of-plane thrust angle

Ω Longitude of ascending node of an orbit

ω Angular position from the ascending node of an orbit to the spacecraft; argument of perifocus of an orbit

I. INTRODUCTION

HILTOP is a Phase A performance analysis computer program that has been developed explicitly for the purpose of generating optimum electric propulsion trajectories that are of interest for the exploration of the solar system. The program contains a propulsion system model that assumes jet exhaust speed (specific impulse) is held constant throughout the flight, while power and thrust may either be held constant, to simulate nuclear electric, or varied with solar distance, to simulate solar electric propulsion. The thrust direction time history and the engine on-off times are determined by the program to extremize a preselected performance index. The indirect optimization method is employed for this purpose. A basic knowledge of optimization theory is required to understand this report. For a discussion of optimization theory, see Reference [1].

The electric propulsion system is permitted to operate throughout the heliocentric flight. The initial conditions of the heliocentric flight are assumed to be established impulsively by a conventional launch vehicle. Two distinct problem formulations are available. In the launch vehicle dependent formulation, the initial spacecraft mass (i.e., the payload of the launch vehicle) is a specified function of the launch hyperbolic excess speed and launch parking orbit inclination, and these two parameters are available as independent parameters to optimize the distribution of performance between the launch vehicle and the electric propulsion system. In the launch vehicle independent formulation, the reference power is specified and the initial spacecraft mass is optimized for a given launch excess speed to maximize net spacecraft mass. In either formulation the hyperbolic geocentric trajectory ultimately established by the launch vehicle is then considered from the viewpoint of asymptotic expansion theory and the spacecraft's motion is added to the motion of the Earth relative to the Sun. Only zero order terms of the expansion are retained such that the initial heliocentric position of the spacecraft is equal to the position of the Earth on the prescribed launch date, and the initial heliocentric velocity of the spacecraft is equal to the vector sum

of the Earth's heliocentric velocity and the launch hyperbolic excess velocity. The direction of the launch excess velocity is determined as part of the optimization problem.

HILTOP may simulate missions having as many as four targets (celestial objects) along a trajectory. One target is designated as the "primary" target (which may be absent in such missions as, for example, extra-ecliptic probes). In addition, up to three "intermediate" targets are permissible, such that the intermediate targets are visited prior to the primary target. At present, intermediate targets must be relatively massless objects such as comets and asteroids, because the gravitational perturbing effect of an intermediate target on the spacecraft is not coded into the program. In addition, the spacecraft is optionally permitted to swing-by the primary target and continue onward ballistically to up to 5 "post-swingby" targets. A multiple-target mission may consist of any combination of flybys, rendezvous, and stopovers involving the intermediate targets including possible sample retrievals and dropoffs of instrument packages.

A power degradation model has been incorporated into the formulation of HILTOP. The model allows a single parameter (denoted "characteristic degradation time") to describe the power degradation behavior of an electric propulsion spacecraft to a degree which fundamentally affects the solution to the trajectory optimization problem.

The option of simulating spacecraft housekeeping power applies to solar electric propulsion with specified reference power. The housekeeping power is a specified constant power generated by the solar arrays and shunted away from the thruster power-conditioners and directly to the spacecraft payload for "housekeeping" purposes. A solution to the problem of optimizing electric propulsion heliocentric trajectories, including the effects of geocentric launch asymptote declination on launch vehicle performance capability, is developed using variational calculus techniques. The model of the launch vehicle per-

formance includes a penalty associated with a non-easterly launch plus another penalty arising from a non-coplanar launch from the parking orbit. Provisions for range safety constraints are included. Optimal trajectories will generally have the launch excess velocity offset from the initial primer vector.

The program's ability to simulate all-ballistic missions includes powered and unpowered multiple swingby missions with an optional deep space burn. This capability renders HILTOP a powerful tool for ballistic mission design and optimization, with tremendous flexibility for creating imaginative multi-target mission profiles.

For planetary orbiter or asteroid or comet rendezvous missions, a computational technique similar to that for launch is provided to include a high-thrust retro maneuver to achieve the desired arrival conditions at the primary target. The arrival hyperbolic excess speed at the primary target is available as an independent parameter to optimize the distribution of performance between the retro stage, of specified thrust and specific impulse, and the electric propulsion system.

The use of the zero order asymptotic matching to account for high-thrust maneuvers in the vicinity of a planet permits all trajectory computations to be carried out in the heliocentric reference frame where a central, inverse square gravitational field is assumed. The location and motion of the planets within this system are defined as functions of time through an analytic ephemeris routine which contains osculating planetary orbital elements which are quadratic functions of time. Comets and asteroids are assumed to have constant orbital elements. The motion of the spacecraft in the heliocentric reference frame under the influence of the electric propulsion system is governed by a set of first and second order ordinary differential equations, known as the state equations. Associated with the state equations is another set of first and second order ordinary differential equations, known as the adjoint equations, which are inherent in the application of the indirect method of optimization. These two sets of equations must be solved

simultaneously. During thrust phases the solution is obtained by numerical integration; however, during coast phases, an analytic solution of the differential equations is known and is employed.

The program is coded to yield a complete optimum solution by the indirect method only for the problem of maximizing net spacecraft mass. The reason for the restriction to a single performance index for the complete solution is that the transversality conditions, which comprise a portion of the Necessary Conditions of the solution, are dependent upon the choice of performance index and only one set of these conditions is presently coded. Coincidentally, however, a complete set of Necessary Conditions is also available for the problem of minimum flight time with fixed net spacecraft mass because the transversality conditions for this problem are identical to those for maximum net spacecraft mass with fixed flight time. A large variety of specific problems may be posed within the framework of these two general problems.

The program iterator routine, whose primary function is to solve the boundary value problem that arises in all trajectory optimization problems, is, in fact, a generalized parameter optimization package. The iterator has two basic modes of operation: (1) the satisfy mode in which the sole purpose is to satisfy all specified boundary conditions, and (2) the improve mode in which a gradient technique is employed to improve a selected performance index while maintaining satisfaction of the specified boundary conditions. This iterator may be used in the following manner. If the specific problem to be solved is contained in one of the two general classes of problems indicated in the preceding paragraph, then all Necessary Conditions, including transversality conditions, are available for evaluation in the program. These transversality conditions are included as part of the boundary conditions, and there results a two point boundary value problem with an equal number of boundary conditions and unknown parameters. A solution of this boundary value problem is assumed to be a solution of the original optimization problem (specified problem to be solved); consequently,

the complete solution to the original problem is assumed to be obtained upon the successful convergence in the satisfy mode. If, however, all of the required transversality conditions are not available for evaluation within the program, as in the case of a performance index other than as indicated in the preceding paragraph, then there will exist more independent parameters than boundary conditions that can be invoked. Thus, an infinite number of solutions exists to the boundary value problem posed, and all degrees of freedom may be used to improve the selected performance index. For such a problem, the iterator first solves the overdetermined boundary value problem in the satisfy mode, and then proceeds to the improve mode, in which the performance index is successively improved while maintaining approximate satisfaction of the boundary conditions. When the performance index can no longer be improved on successive iterations, the iterator assumes that the extremum has been successfully isolated and terminates the search. An important feature of the improve mode is that any program parameter that is available for specification as a boundary condition may be chosen as a performance index. Consequently, the program provides considerable flexibility in treating a variety of problems. The primary drawback of the improve mode is that it is costly and time consuming to use extensively because of the normally slow convergence rates concomitant with direct techniques, and therefore it is highly recommended that the problem of interest be posed within the framework of the satisfy mode whenever possible.

II. FORMULATION

A. SPACECRAFT AND TRAJECTORY MODELS.

The following discussion is oriented toward the programming logic aspects of the HILTOP computer program. For the sake of simplicity and clarity, the discussion of solar array radiation degradation is discussed separately in Section C.

1. Spacecraft Mass Components. The spacecraft is composed of an electric propulsion system and associated tankage and propellant masses, a structure mass component, a retro propulsion component (for maneuvers about a primary target), a set of instrument package masses to be dropped at intermediate targets and a net spacecraft mass as follows:

$$m_o = m_{ps} + m_p + m_t + m_s + m_r + \sum_{i=1}^{n-1} m_{drop\ i} + m_{net} , \tag{1}$$

where m_o is the initial spacecraft mass; m_{ps}, m_p, m_t are the electric propulsion engine and powerplant, propellant and tankage masses, respectively; m_s is the structure component; m_r is the retro propulsion mass; $m_{drop\ i}$ is the instrument package mass left at the i^{th} target; and m_{net} is net spacecraft mass (payload). In the analysis to follow, the subscript o denotes the launch body and n the primary (final) target. The net spacecraft mass consists of the scientific instruments, communications, navigation, and other engineering hardware, shielding, and any other mass components required to carry out the mission of interest.

Under one program operating mode, known as the launch vehicle dependent mode, the initial spacecraft mass is governed by the performance capability of a launch vehicle according to the relation,

$$m_o = b_1 e^{[-v_c/b_2]} - b_3 , \tag{2}$$

where

$$v_c = \left[v_{\infty o}^2 + v_e^2 \right]^{\frac{1}{2}} , \tag{3}$$

provided that the declination of the departure asymptote at Earth escape does not exceed the latitude of the launch site (in magnitude). Whenever the departure asymptote declination exceeds the launch site latitude in magnitude, the above expression for the characteristic velocity, v_c, should be expanded to allow non-coplanar burns by the launch vehicle and/or non-due-East launches from the launch site. The equations for this more complicated case of a non-coplanar launch are treated in a subsequent paragraph. In expressions (2) and (3), $v_{\infty o}$ is the departure hyperbolic excess speed, v_e is an internal constant equal to the escape speed at 185 km altitude above the Earth's surface, and b_1, b_2, b_3 are constants which define the performance capability of a given launch vehicle. These constants may either be input directly or taken from an internal table of constants that have been pre-computed for selected launch vehicles. The constants in the internal table were generated using a least squares algorithm and data from Reference [2]. The payload capabilities of the specified launch vehicles were curve fit to the above equation for initial spacecraft mass.

Under a second operating mode, known as the launch vehicle independent mode, the initial spacecraft mass is completely unconstrained. The program then determines the optimum initial mass which results in the maximum net spacecraft mass for given reference power. The launch excess speed may be either fixed or optimized.

The electric propulsion engine mass is given by,

$$m_{ps} = p_{ref} [\alpha_t + (1 + \Delta p) \alpha_a], \tag{4}$$

where p_{ref} is the reference power (see Electric Propulsion System) α_t, is the specific mass of the thruster and power conditioning subsystem, α_a is the specific mass of the arrays, and Δp is the ratio of housekeeping to reference power, an input constant. The electric propulsion propellant mass m_p is obtained by integrating the derivative of mass ratio over all thrusting arcs and employing the equation,

$$m_{pn} = m_o (1-\nu_n) + \sum_{i=1}^{n-1} (m_{samp\ i} - m_{drop\ i}) , \quad (5)$$

where ν_n is the mass ratio at the primary target (i.e., prior to the optional retro maneuver) and $m_{samp\ i}$ is the sample mass picked up at the i^{th} target.

The sample masses and drop masses are specified as linear functions of the initial mass, as follows:

$$m_{samp\ i} = m_o k_{samp\ i} ; \quad m_{drop\ i} = m_o k_{drop\ i} , \quad (6)$$

where $k_{samp\ i}$ and $k_{drop\ i}$ are inputs and are available as independent parameters of the boundary value problem. Both $m_{samp\ i}$ and $m_{drop\ i}$ are available as dependent parameters.

The electric propulsion propellant tankage mass and structure mass are computed, respectively,

$$m_t = k_t m_p , \quad (7)$$

$$m_s = k_s m_o , \quad (8)$$

where k_t and k_s are input constants.

The total retro mass array is given by the sum $m_r = m_{rp} + m_{rst}$ where the retro propellant requirement, m_{rp}, is given by the following:

$$m_{rp} = (m_o \nu_n - j_{ps} m_{ps} - j_t m_t) e_x , \quad (9)$$

where m_{ps} and m_t are the electric propulsion system and tankage masses, respectively; j_{ps} and j_t are input jettison indicators set equal to one if the electric propulsion engine mass and tankage mass components are to be jettisoned prior to the retro maneuver and equal to zero otherwise; and e_x is given by

$$e_x = 1 - e^{[-\Delta v'/c_r]} , \tag{10}$$

where $\Delta v'$ is the magnitude of the required velocity increment of the retro stage and c_r is the retro jet exhaust speed, evaluated as the product of the input retro specific impulse and the reference acceleration of gravity ($9.80665\ m/sec^2$). The computation of $\Delta v'$ is discussed in Section B, Part 3, Target Conditions and Spacecraft Constraints.

The retro structure and tankage mass component, m_{rst}, is given by

$$m_{rst} = m_{rs} + k_{rt} m_{rp} , \tag{11}$$

where m_{rs} is the input structural mass and k_{rt} is the input retro tankage factor. The burn time associated with the retro maneuver, t_b, is computed as a function of the input engine parameters,

$$t_b = \frac{m_{rp} c_r}{f_r} , \tag{12}$$

where f_r is the input thrust level of the retro stage.

2. <u>Electric Propulsion System.</u> The independent parameters associated with the propulsion system are reference thrust acceleration, g, and jet exhaust speed, c. g is the thrust magnitude at 1 AU from the sun divided by the initial mass, and is not to be confused with the acceleration of gravity at the Earth's surface, which is not used (as a symbol) in this document. The instantaneous thrust acceleration is computed by,

$$a = \frac{g\gamma}{\nu} h_\sigma , \tag{13}$$

where γ is the instantaneous power ratio (described below), ν is the instantaneous mass ratio m/m_o, and h_σ is a step function equal to one if the engine is operating and equal to zero otherwise. The propulsion system is assumed to

operate at constant jet exhaust speed. The instantaneous power, p, delivered to the power processors, is computed by

$$p = g m_o c \gamma h_\sigma / 2\eta = h_\sigma \gamma p_{ref} , \tag{14}$$

where η is the engine efficiency and the reference power, p_{ref}, is the power delivered to the power processors at 1 AU from the sun.

The thrust magnitude, f, generated by the electric propulsion system is given by

$$f = g m_o \gamma h_\sigma = \frac{2\eta p}{c} . \tag{15}$$

The propulsion system efficiency is assumed to be a function of the jet exhaust speed and is given by

$$\eta = \frac{b c^2}{c^2 + d^2} + e , \tag{16}$$

where b, d, and e are constants specified in program input.

The power ratio γ is defined

$$\gamma = \frac{p}{p_{ref}} . \tag{17}$$

The electrical power model of the electric propulsion system is specified through an input option indicator. For nuclear electric spacecraft, the power remains constant throughout the trajectory. For solar electric spacecraft, the power is modelled as a function of solar distance and solar array orientation relative to the sunline. The six options available are given below:

Option 1 Not presently used.

Option 2 $$\gamma = (1 + \Delta p)\, d \sum_{i=0}^{4} a_i d^{i/4} - \Delta p , \tag{18}$$

where d represents the density of photons impinging the solar arrays. The definition of d is

$$d = \frac{\cos \chi}{r^2}, \tag{19}$$

where χ is the angle between the normal to the array and the spacecraft-sun line. For Option 2, $\chi \equiv 0$.

The coefficients a_i comprise a set of internal constants with the following values:

i	a_i
0	0.6270
1	5.3054
2	-10.0376
3	7.1073
4	-2.0021

These values are consistent with solar distance r expressed in AU. Also, it is possible to input the coefficients a_i to the program. (See HILTOP Input). The program expects the γ-curve to peak at some distance r_{peak} from the sun, and r_{peak} is about 0.665 AU for the coefficients listed above.

Option 3 $\gamma = 1$.

Option 4 Same as Option 2 for r greater than r_{peak}. For r less than r_{peak}, γ is held constant at the peak value by setting $\cos \chi = (r/r_{peak})^2$.

Option 5 Same as Option 2 with the side condition that $\gamma \leq$ GAMMAX where GAMMAX is an input constant. This is achieved by setting $\cos \chi = (r/r_c)^2$ where r_c is the distance at which γ = GAMMAX.

Option 6 Same as Option 2 except γ is held constant at the peak value everywhere.

These five available options may be described roughly as follows. Option 2 is the current projected-state-of-the-art basic SEP power law. Option 3 is the nuclear electric propulsion (NEP) power law. Options 4, 5, and 6 are variations of Option 2, in which the solar panels are either shielded or tilted away from the sun at the smaller solar distances, and in Option 6 it is assumed that reflecting flaps gather the required solar energy at the greater solar distances.

3. Target Ephemerides. When it is desired to generate trajectories involving targets which are specific celestial objects, the program includes the capability of internally generating a specific target's state (position and velocity) at any given time. If a target is a major celestial object in terms of mass (Mercury through Pluto), the orbital elements eccentricity, argument of perihelion, node, inclination and mean anomaly are computed as quadratic power series in time, and the semi-major axis remains constant with time. If a target is a minor celestial object in terms of mass (comet or asteroid), the orbital elements are constant with time. In either case, Kepler's equation $M = E - e \sin E$ is solved iteratively for the eccentric anomaly E; in this equation, M is the mean anomaly and e is the eccentricity. Finally, the target's position, velocity and acceleration are expressed in a Cartesian coordinate system with the x-axis directed toward the vernal equinox of date, the z-axis pointing toward the north ecliptic pole, and the y-axis completing the right-handed system.

4. Differential Equations. The attainment of an optimum electric propulsion trajectory requires the repeated simultaneous solution of two sets of differential equations, the state equations and the adjoint, or Euler-Lagrange, equations. The state equations are comprised of the equations of motion of the spacecraft plus the equations describing the change of the spacecraft as a function of time.

The motion of the spacecraft is assumed to take place in an inverse square heliocentric gravitational field and to be influenced by an electric propulsion system

with thrust directed optimally. The second order differential equations of motion are given by

$$\ddot{R} = h_\sigma \frac{g\gamma}{\nu} \bar{e}_t - \frac{\mu R}{r^3} , \tag{20}$$

where R is the heliocentric position of the spacecraft; $r = |R|$; μ is the sun's gravitational constant; g is the reference thrust acceleration (thrust magnitude at 1 AU from the sun divided by initial mass); γ is the normalized power variation which may be a function of solar distance and solar array orientation; ν is the mass ratio m/m_o; $\bar{e}_t$ is a unit vector in the direction of thrust; and h_σ is the step function control variable associated with the thrust switch function. Only the sun's gravitational effect on the spacecraft motion is taken into account, the effects of all other celestial objects being neglected during heliocentric flight. The complete set of state equations for this problem includes the equations of motion above and the following three first order differential equations:

$$\dot{\nu} = - h_\sigma \frac{g\gamma}{c} , \tag{21}$$

$$\dot{g} = 0 , \tag{22}$$

$$\dot{c} = 0 , \tag{23}$$

where g and c are the propulsion system parameters, defined previously, which are constant on a given trajectory. In addition, the following differential equations

$$\dot{\tau} = h_\sigma , \tag{24}$$

$$\dot{\phi} = 0 , \tag{25}$$

where τ is the propulsion time and ϕ is the thrust cone angle (the angle between the radius and thrust vectors), are considered state equations for problems with constrained propulsion time and fixed cone angle, respectively. The condition of fixed thrust cone angle is implemented through the latter differential equation in conjunction with the side condition,

$$\bar{e}_t \cdot R - r\cos\phi = 0. \qquad (26)$$

The differential equations which govern the behavior of the adjoint variables are given by

$$\ddot{\Lambda} = \frac{3\mu}{r^5}(\Lambda \cdot R)R - \frac{\mu\Lambda}{r^3} + \frac{h_\sigma g}{\nu}\gamma' \frac{R}{r}\left(\Lambda \cdot \bar{e}_t - \frac{\nu}{c}\lambda_\nu\right)$$

$$+ \lambda_x\left(\bar{e}_t - \frac{R}{r}\cos\phi\right), \qquad (27)$$

$$\dot{\lambda}_\nu = \frac{h_\sigma g\gamma}{\nu^2}(\Lambda \cdot \bar{e}_t), \qquad (28)$$

$$\dot{\lambda}_g = -h_\sigma \frac{\gamma}{\nu}\left(\Lambda \cdot \bar{e}_t - \frac{\nu}{c}\lambda_\nu\right), \qquad (29)$$

$$\dot{\lambda}_c = -\frac{h_\sigma g\gamma}{c^2}\lambda_\nu, \qquad (30)$$

where $\gamma' = \partial\gamma/\partial r$; Λ is the familiar primer vector which is adjoint to the velocity; λ_ν is the adjoint variable associated with the mass ratio; λ_g is the adjoint variable associated with the reference thrust acceleration; λ_c is the adjoint variable associated with the jet exhaust speed; and λ_x is a Lagrange multiplier that is identically zero if thrust cone angle is unconstrained and defined

$$\lambda_x = -h_\sigma \frac{g\gamma}{\nu}\frac{\Lambda \cdot (\bar{m} \times \bar{e}_t)}{R \cdot (\bar{m} \times \bar{e}_t)}, \qquad (31)$$

if the cone angle is fixed. The unit vector $\bar{m}$ is defined

$$\bar{m} = \frac{R \times \Lambda}{|R \times \Lambda|}. \qquad (32)$$

Also, if thrust cone angle is fixed, an additional adjoint variable λ_ϕ is introduced which is adjoint to the cone angle ϕ, and its differential equation is

$$\dot{\lambda}_{\phi} = \lambda_{x} R \cdot (\bar{m} \times \bar{e}_{t}) . \tag{33}$$

Finally, a constraint on propulsion time requires the introduction of λ_{τ}, an adjoint variable associated with propulsion time. Because propulsion time does not appear explicitly in the state equations, λ_{τ} is a constant, i.e.,

$$\dot{\lambda}_{\tau} = 0 . \tag{34}$$

If propulsion time is optimized, the constant value of λ_{τ} is zero.

5. Optimality Conditions. The control variables available for optimization along the trajectory include the unit thrust direction vector $\bar{e}_{t}$ and the step function h_{σ}. The application of the Maximum Principle of optimal control theory leads to the result that the proper choice of the control variables is that which maximizes the variational Hamiltonian, h_{v}, at each point along the path. The variational Hamiltonian for the problem formulated here may be written

$$h_{v} = h_{\sigma} \frac{g\gamma}{\nu} \left(\Lambda \cdot \bar{e}_{t} - \frac{\nu}{c} \lambda_{\nu} + \frac{\nu}{g\gamma} \lambda_{\tau}\right) - \frac{\mu}{r^{3}} (\Lambda \cdot R) - \dot{\Lambda} \cdot \dot{R} . \tag{35}$$

Since the quantities $g\gamma/\nu$ and h_{σ} are non-negative, it is obvious that h_{v} is maximized with respect to $\bar{e}_{t}$ by aligning $\bar{e}_{t}$ with Λ, and this is the choice made if the thrust cone angle is unconstrained. In the event of a constraint on cone angle, one simply chooses $\bar{e}_{t}$ as close to Λ as the constraint will permit. By considering the intersection closest to Λ of a circular cone about R (with half-angle equal to ϕ) and the $R - \Lambda$ plane, one easily determines the optimum $\bar{e}_{t}$, subject to the fixed cone angle constraint, to be

$$\bar{e}_{t} = \frac{1}{r}\left[R \cos\phi + (\bar{m} \times R) \sin\phi\right], \tag{36}$$

with $\bar{m}$ as defined in expression (32).

The proper choice of h_{σ} is seen to depend on the sign of the switch function σ, defined by

$$\sigma = \Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu + \frac{\nu}{g\gamma} \lambda_\tau . \tag{37}$$

Again, since $g\gamma/\nu$ is non-negative, the variational Hamiltonian is maximized with respect to h_σ by choosing h_σ as follows:

$$h_\sigma = 0 \quad \text{if } \sigma < 0 , \tag{38a}$$

$$h_\sigma = 1 \quad \text{if } \sigma > 0 . \tag{38b}$$

Recall that the permissible values of h_σ are limited to zero and one.

6. Integration. Integration of the differential equations associated with the state and adjoint variables is done in two distinct modes which depend upon the thrust switch function, σ. These two modes are discussed below.

Thrust

Numerical integration is required on thrust intervals. The independent variable of integration is the generalized universal anomaly, u. The relationship between derivatives with respect to time and u is given by

$$\frac{du}{dt} = r^{-n} , \tag{39}$$

where r is the spacecraft's solar distance and n is an input constant (not to be confused with subscript n used elsewhere). Δu, the independent variable interval used for the integration, is an input constant. Denoting derivatives with respect to u with the prime, the conversions from time to u derivatives are

$$x' = r^n \dot{x} , \tag{40}$$

$$x'' = r^{2n} \left(\frac{R \cdot \dot{R}}{r^2} n \dot{x} + \ddot{x} \right) . \tag{41}$$

A standard fourth-order Runge-Kutta numerical integration technique for first-order differential equations is used. A value of n equal to 1.5 will regularize the differential equations with respect to the mathematical singularity associated with the gravitational force at the point $r = 0$ (where the sun is located). This is accomplished by inherently taking smaller steps in time (which is an integrated quantity) when closer to the sun and larger steps when farther from the sun, assuming Δu = constant. Equation (39), however, allows the removal of only the solar singularity from the optimal rocket problem, and has no provision for the other singularity, which is characterized by an extremely high thrust rotation rate and occurs whenever the primer vector passes relatively close to the origin of primer-space $(\Lambda = 0)$ during a thrust phase. The difficulty associated with the primer-origin singularity is lessened by continuously cutting down the step size Δu as the primer origin is approached. It is noted in passing that when forced-thrusting is invoked for an optimum flyby mission, the primer-origin singularity will occur at the flyby target (as will become apparent in the discussion of transversality conditions in a later section).

Coast

During any coast phase, the two-body equations of motion and the associated adjoint equations are known to possess analytic solutions obtainable in closed form. The particular form of the solution used in HILTOP is derived in Reference [3] and is simply repeated here. This solution employs a universal variable, β, defined implicitly through the differential equation

$$\dot{\beta} = \frac{\sqrt{\mu}}{r} , \tag{42}$$

where μ is the gravitational constant of the attracting body.

For elliptic, two-body trajectories, this equation has the solution

$$\beta - \beta_o = \sqrt{a}\ (E - E_o) , \tag{43}$$

where E is the eccentric anomaly and a is the semi-major axis.

The problem to be solved is that of evaluating the state and adjoint variables at $\beta = \beta_o + \Delta\beta$ given the values of these variables at $\beta = \beta_o$. This is accomplished as follows. Given R_o and $\mathring{R}_o$ (the state at $\beta = \beta_o$) compute

$$
\begin{aligned}
r_o &= (R_o \cdot R_o)^{\frac{1}{2}} , \\
v_o^2 &= \mathring{R}_o \cdot \mathring{R}_o , \\
d_o &= R_o \cdot \mathring{R}_o , \\
\frac{1}{a} &= \frac{2}{r_o} - \frac{v_o^2}{\mu} , \\
\epsilon &= (\Delta\beta)^2/a = (E - E_o)^2 .
\end{aligned}
\tag{44}
$$

Then, using the truncated infinite series expression

$$
G_i = (\Delta\beta)^i \sum_{k=0}^{16} \frac{(-\epsilon)^k}{(2k+i)!} , \tag{45}
$$

compute the functions G_i for $i = 5$ and 4. Thereafter, the functions G_i, $i = 0, 1, 2, 3$ are computed from the recursion formula,

$$
G_i = \frac{(\Delta\beta)^i}{i!} - \frac{1}{a} G_{i+2} , \tag{46}
$$

and are employed to evaluate the familiar f and g functions, i.e.,

$$
\begin{aligned}
f &= 1 - \frac{G_2}{r_o} , \\
g &= \frac{1}{\sqrt{\mu}} \left(r_o G_1 + \frac{d_o}{\sqrt{\mu}} G_2\right) , \\
r &= r_o G_o + \frac{d_o}{\sqrt{\mu}} G_1 + G_2 ,
\end{aligned}
\tag{47}
$$

$$t - t_o = g + \frac{G_3}{\sqrt{\mu}} ,$$

$$\dot{f} = - \frac{\sqrt{\mu}\, G_1}{r\, r_o} ,$$

$$\dot{g} = 1 - \frac{G_2}{r} , \tag{47 cont.}$$

$$R = f R_o + g \dot{R}_o ,$$

$$\dot{R} = \dot{f} R_o + \dot{g} \dot{R}_o ,$$

which provide the state and time at the given value of $\beta = \beta_o + \Delta\beta$. g in this section is not to be confused with the reference thrust acceleration used widely throughout this document. The corresponding equations for the adjoint variables are:

$$\lambda_i(t) = \frac{\partial x_i(t)}{\partial x_j(t_o)} \lambda_j(t_o) + \frac{\partial x_i(t)}{\partial \dot{x}_j(t_o)} \dot{\lambda}_j(t_o), \tag{48}$$

$$\dot{\lambda}_i(t) = \frac{\partial \dot{x}_i(t)}{\partial x_j(t_o)} \lambda_j(t_o) + \frac{\partial \dot{x}_i(t)}{\partial \dot{x}_j(t_o)} \dot{\lambda}_j(t_o) , \tag{49}$$

where $i, j = 1, 2, 3,$ and repeated subscripts in the same term imply summation over the range of the subscripts. The variables $x_i(t)$ represent the three Cartesian components of $R(t)$ while the $\lambda_i(t)$ represent the components of $\Lambda(t)$. The partial derivatives indicated are given as follows, with δ_{ij} denoting the Kronecker delta function:

$$\frac{\partial x_i}{\partial x_{o_j}} = (\dot{x}_i - \dot{x}_{o_i})\left[\frac{p_1 x_{o_j}}{r_o^3} + \frac{r}{\mu} (\dot{x}_j - \dot{x}_{o_j})\right] + f\,\delta_{ij} + \frac{x_{o_j}}{r_o^3} \left[\left(G_2 + \frac{2G_4 - \Delta\beta G_3}{r_o}\right) x_{o_i} + (3G_5 - \Delta\beta G_4) \frac{\dot{x}_{o_i}}{\sqrt{\mu}} \right], \tag{50}$$

$$\frac{\partial x_i}{\partial \dot{x}_{o_j}} = \frac{\dot{x}_i - \dot{x}_{o_i}}{\mu}\left[p_1 \dot{x}_{o_j} - G_2 x_{o_j}\right] + \frac{\dot{x}_{o_j}}{\mu}\left[(2G_4 - \Delta\beta G_3)\frac{x_{o_i}}{r_o} + (3G_5 - \Delta\beta G_4)\frac{\dot{x}_{o_i}}{\sqrt{\mu}}\right] + g\delta_{ij}\,, \tag{51}$$

$$\frac{\partial \dot{x}_i}{\partial x_{o_j}} = -\frac{\mu x_i}{r^3}\left[\frac{p_1 x_{o_j}}{r_o^3} + \frac{r}{\mu}(\dot{x}_j - \dot{x}_{o_j})\right] + \frac{\dot{x}_i - \dot{x}_{o_i}}{r}\left[\frac{p_2 x_{o_j}}{r_o^3} - \left(\frac{x_{o_j}}{r_o} G_o + \frac{\dot{x}_{o_j}}{\sqrt{\mu}} G_1\right)\right]$$

$$+ \frac{x_{o_j}}{r\, r_o^3}\left[\left(G_1 + \frac{G_3 - \Delta\beta G_2}{r_o}\right)\sqrt{\mu}\; x_{o_i} + (2G_4 - \Delta\beta G_3)\,\dot{x}_{o_i}\right] + \dot{f}\,\delta_{ij}\,, \tag{52}$$

$$\frac{\partial \dot{x}_i}{\partial \dot{x}_{o_j}} = -\frac{x_i}{r^3}\left[p_1 \dot{x}_{o_j} - G_2 x_{o_j}\right] + \frac{\dot{x}_i - \dot{x}_{o_i}}{r\sqrt{\mu}}\left[\frac{p_2 \dot{x}_{o_j}}{\sqrt{\mu}} - G_1 x_{o_j}\right]$$

$$+ \frac{\dot{x}_{o_j}}{\mu r}\left[(G_3 - \Delta\beta G_2)\;\frac{\sqrt{\mu}}{r_o}\, x_{o_i} + (2G_4 - \Delta\beta G_3)\,\dot{x}_{o_i}\right] + \dot{g}\,\delta_{ij}\,, \tag{53}$$

where

$$p_1 = \frac{1}{\sqrt{\mu}}\left[3G_5 - \Delta\beta G_4 + \frac{d_o}{\sqrt{\mu}}(2G_4 - \Delta\beta G_3) + r_o\,(G_3 - \Delta\beta G_2)\right]\,, \tag{54}$$

$$p_2 = 2G_4 - \Delta\beta G_3 + \frac{d_o}{\sqrt{\mu}}\,(G_3 - \Delta\beta G_2) - r_o \Delta\beta G_1\,. \tag{55}$$

The values of the derivatives of all other state and adjoint variables vanish during coast phases; therefore, their solutions are trivial.

7. Units. The internal units of the program are kilogram for mass, AU for distance and tau for time, which implies speed in EMOS. (One tau is the time required for a massless particle to travel one radian in a circular orbit of radius 1 AU about the sun). To convert from internal units to the MKS system, multiply by the following constants:

$$\text{Distance} - r = 1.49599 \times 10^{11} \text{ meters} = \text{one AU}$$

$$\text{Acceleration} - \mu/r^2 = 5.9301282604 \times 10^{-3} \text{ m/sec}^2$$

$$\text{Velocity} - \sqrt{\mu/r} = 29784.916613 \text{ m/sec} = \text{one EMOS} = \text{one AU per tau}$$

$$\text{Time} - \sqrt{r^3/\mu}/86,400 = 58.132440991 \text{ days} = \text{one tau}$$

A solar gravitational constant of $1.32715445 \times 10^{20}$ m^3/sec^2 is assumed. There is no conversion from input to internal units for the initial Lagrange multipliers, which are required to start a trajectory. Hence the input values of the multipliers are consistent with the internal units of the state variables; i.e., mass in kilograms, distance in AU, and time in tau.

When evaluated in internal units, the equations presented previously yield power in units of kg - AU^2/tau^3 and thrust in units of kg - AU/tau^2. To obtain these quantities in the MKS units (i.e., power in watts, thrust in newtons), multiply by the following factors:

$$\text{Power} - \sqrt{\mu^3/r^5} = 176.6283757392 \text{ m}^2/\text{sec}^3$$

$$\text{Thrust} - \mu/r^2 = 5.9301282604 \times 10^{-3} \text{ m/sec}^2$$

Thrust in pounds is obtained by dividing the thrust in newtons by the factor 4.4482221811.

B. BOUNDARY VALUE PROBLEM

1. Boundary Constraints. The HILTOP program currently provides for nearly 100 different dependent parameters (end conditions), although certain of these are coded mutually exclusive. There are about half as many independent parameters available in the program and therefore a subset of the dependent parameter array must be chosen for a well-posed problem. The independent parameters include the adjoint variables (i.e., the primer vector and its time derivative at the start of each possible trajectory segment and the adjoint variables associated with mass ratio, degradation time and propulsion time at the start of the first trajectory segment), the reference thrust acceleration, the jet exhaust speed, the launch asymptote declination, the launch time and hyperbolic excess speed and the times and excess speeds at the various possible targets. Also included are the thrust cone angle (if constrained), the inclination of the parking orbit about Earth, the heliocentric departure velocity, and the sample-mass and drop-mass factors at each possible intermediate target. The dependent parameters include the spacecraft position and velocity differences with respect to each possible target along a trajectory, the launch time and hyperbolic excess speed and the times and excess speeds at the various possible targets, and, indeed, all of the independent variables (except the primer vector time derivative) are available also as dependent variables, as this allows the analyst to let the program iterator move one trajectory solution toward another trajectory solution. This provides wider flexibility and more control in solving the boundary value problem, particularly in instances where successive cases are employed to sweep a range of values of one or more of these parameters. In addition, total flight time, propulsion time, degradation time, net spacecraft mass, reference power, final solar distance, and the transversality conditions which yield optimum flybys, launch time and excess speed, target encounter times, reference power, reference thrust acceleration, jet exhaust speed, launch parking orbit inclination, launch asymptote declination, thrust cone angle, and travel angle are available as dependent conditions to be satisfied. The complete list of options available is found in the section Definitions of Input Parameters.

2. Initial Conditions for State and Adjoint Equations. The launch planet's position P_o and velocity $\dot{P}_o$ are either input directly or computed for the specified launch date using the ephemeris routine that is available in the program. Given these vector quantities, the program computes the spacecraft's initial heliocentric position R_o to coincide identically with the launch planet, $R_o = P_o$. The spacecraft's initial heliocentric velocity may be input directly to the program; however, the program's normal operating mode is to equate the initial velocity to the sum of the velocity of the launch planet and the hyperbolic excess velocity, i.e.,

$$\dot{R}_o = \dot{P}_o + V_{\infty o} \tag{56}$$

where $V_{\infty o}$ is the launch hyperbolic excess velocity. The magnitude $v_{\infty o}$ is available as an independent parameter, and therefore may be either specified or optimized. The direction of V_∞ is usually optimized , although one option does permit partially constraining V_∞ through the geocentric declination which also is available as an independent parameter. The initial mass ratio ν_o is specified to be one on all trajectories.

The adjoint variables at the start of each possible trajectory segment, which are contained in the list of independent parameters, are direct inputs to the program for the first trajectory of an iteration sequence, except that some of the adjoint variables associated with departing from an intermediate target may be generated internally by the program as being continuations from the previous trajectory segment. For all subsequent trajectories in an iteration sequence, these adjoint variables either remain as input or are varied by the iterator. A value for the initial adjoint variable associated with mass ratio must be input to the program, and a value for the initial adjoint variable associated with propulsion time may be input (the default-value of zero yields optimum propulsion time). The values of the initial adjoint variables not included in the list of independent parameters (i.e., λ_g, λ_c, and λ_ϕ) are set to zero because the specific initial values assigned to these variables are arbitrary.

3. <u>Target Conditions and Spacecraft Constraints.</u> Three basic options are available for specifying the target conditions with each option being designed for a particular type of mission. Within each option, considerable flexibility is available for treating many variations of a mission type. The three options will be referred to as the ephemeris, the open angle, and the extra-ecliptic options.

As the name implies, the ephemeris option is employed for missions in which the primary and/or intermediate targets are celestial bodies for which the positions and velocities (of the bodies) are either input directly or computed using the analytic ephemeris. Denoting a specific target's position and velocity as P_i and $\dot{P}_i$, respectively, a constraint on the spacecraft position R_i is imposed by nulling the position error; i.e., by forcing the satisfaction of the equation

$$\Delta R_i = R_i - P_i = 0. \tag{57}$$

Similarly, a constraint on the spacecraft velocity $\dot{R}_i$ is imposed by nulling the velocity error,

$$\Delta \dot{R}_i = \dot{R}_i - \dot{P}_i - V_{\infty i} = 0 , \tag{58}$$

where $V_{\infty i}$ is the arrival excess velocity at the i^{th} target. These equations apply both to intermediate and the primary targets.

The open angle option is restricted to problems of two-dimensional motion in the x-y plane. The option is designed specifically for the problem of open angle transfer from a given point to a specified solar distance r_f. This target condition is written, simply,

$$|R_n| = r_f , \tag{59}$$

where the subscript n denotes the primary, or final, target. The capability of imposing circular orbit conditions at this solar distance is also available. This vector target condition is written in the form of a velocity error as follows:

$$\Delta\dot{R} = \dot{R}_n - \sqrt{\frac{\mu}{r_f}} \left(\bar{k} \times \frac{R_n}{|R_n|}\right) - V_{\infty n} = 0, \tag{60}$$

where μ is the gravitational constant of the sun and $\bar{k}$ is a unit vector along the z-axis.

The extra-ecliptic option provides the capability of targeting to a final perihelion distance r_f, inclination to the ecliptic i_f, and orbital eccentricity e_f starting from a launch planet of specified position and velocity. The formulation imposes the condition that the spacecraft be at perihelion at the final time. Thus, four of the six conditions required to completely define the final position and velocity are specified. The two open degrees of freedom lead to a like number of transversality conditions which are

$$H \cdot C = 0, \tag{61}$$

$$\bar{k} \cdot C = 0, \tag{62}$$

where H is the angular momentum vector of the final orbit, $\bar{k}$ is the unit vector normal to the ecliptic, and C is the vector constant of the motion defined by

$$C = (R \times \dot{\Lambda}) - (\dot{R} \times \Lambda). \tag{63}$$

These equations may be solved for the osculating orbital elements, Ω, the longitude of ascending node and, ω, the angular position from the ascending node, evaluated at the final time. This leads to the relations

$$\Omega = \tan^{-1}\left[(C \cdot \bar{j})/(C \cdot \bar{i})\right], \tag{64}$$

$$\omega = \tan^{-1}\left[(-\bar{h} \cdot \dot{\Lambda})\, r_f/(\bar{h} \cdot \Lambda)\, v_f\right], \tag{65}$$

where

$$\bar{h} = \cos i_f \bar{k} + \sin i_f (\bar{k} \times C)/|\bar{k} \times C|, \tag{66}$$

$$v_f = \sqrt{\mu(1 + e_f)/r_f}, \tag{67}$$

and where Λ and $\dot{\Lambda}$ are evaluated at the final time. The target conditions are then written as position and velocity errors as follows:

$$\Delta R = r_f \begin{bmatrix} c\,\omega\, c\Omega - s\,\omega\, s\Omega\, c\, i_f \\ c\,\omega\, s\Omega + s\,\omega\, c\Omega\, c\, i_f \\ s\,\omega\, s\, i_f \end{bmatrix} - R = 0\ , \tag{68}$$

$$\Delta \dot{R} = v_f \begin{bmatrix} -s\,\omega\, c\Omega - c\,\omega\, s\Omega\, c\, i_f \\ -s\,\omega\, s\Omega + c\,\omega\, c\Omega\, c\, i_f \\ c\,\omega\, s\, i_f \end{bmatrix} - \dot{R} = 0\ , \tag{69}$$

where s and c denote sine and cosine, respectively, and R and $\dot{R}$ are the final integrated heliocentric position and velocity vectors, respectively.

An alternate set of end conditions for the extra ecliptic mission is also available. The alternate set relaxes the requirement that the final position be at perihelion. The final state is specified in terms of the semi-major axis, eccentricity, and inclination. The other three end conditions are transversality conditions associated with open longitude of node, argument of periapse and true anomaly. The first two of these conditions are given by (61) and (62), and the third is:

$$\frac{\mu}{r}(\Lambda \cdot R) + r^2 (\dot{\Lambda} \cdot \dot{R}) = 0. \tag{70}$$

For either of the first two options above, the capability is provided for evaluating the propellant and structural mass requirements of a high-thrust retro stage which brakes the spacecraft, approaching the primary target along a hyperbolic orbit of excess speed $v_{\infty n}$, into an elliptical capture orbit of pericenter distance r_p and apocenter distance r_a. The retro stage thrust f_r and jet exhaust speed c_r are specified by input. The retro maneuver is assumed

to take place at the periapsis of the approach hyperbola; therefore, the impulsive change in velocity is given by

$$\Delta v = (v_{\infty n}^2 + 2v_p^2)^{\frac{1}{2}} - \left(\frac{2r_a v_p^2}{(r_a + r_p)}\right)^{\frac{1}{2}} , \tag{71}$$

where

$$v_p^2 = \mu_t / r_p , \tag{72}$$

and μ_t is the gravitational constant of the primary target. Provision for including the finite thrust velocity penalty is optionally available. This feature employs the theory developed by Robbins (Reference [4]). The total velocity required, including the velocity penalty, is given by

$$\Delta v' = \Delta v + c_1 e_x f_x , \tag{73}$$

where $\Delta v'$ is solved iteratively with the following equations,

$$c_1 = k_c (v_{\infty n}^2 + v_p^2)/(v_{\infty n}^2 + 2v_p^2), \tag{74}$$

$$k_c = c_r \left(\frac{v_p c_r (m_o \nu_n - j_{ps} m_{ps} - j_t m_t)}{2 r_p f_r} \right)^2 , \tag{75}$$

$$e_x = 1 - e^{(-\Delta v'/c_r)} , \tag{76}$$

$$f_x = 2 - (1 + \frac{2 c_r}{\Delta v'}) e_x , \tag{77}$$

and where j_{ps} and j_t are the jettison flags or indicators defined previously in Section A.

The usual definition of characteristic speed v_c, used in the computation of initial spacecraft mass, is given by equation (3). As stated previously, this definition is valid only if the magnitude of the geocentric declination δ of the launch excess velocity is less than or equal to the latitude of the launch site. If

this condition is violated, then the launch vehicle payload (i.e., the initial spacecraft mass) becomes a function of the direction of $V_{\infty o}$ also. High geocentric declinations of $V_{\infty o}$ can be achieved by establishing a high inclination launch parking orbit, by employing a non-coplanar injection from the parking orbit, or by a combination of both. The usual method of defining launch vehicle performance corresponds to a due-East launch from the ETR. Such a launch yields a parking orbit inclination equal to the launch site latitude, or about 28.5 degrees. The HILTOP model of initial spacecraft mass for high declinations consists of adding to the normal definition of v_c a velocity penalty associated with a non due-East launch, to achieve a greater parking orbit inclination, and a penalty due to the non-coplanar injection maneuver.

The velocity penalty incurred with non due-East launches from the ETR is shown graphically in Reference [2] as a function of the parking orbit inclination. This velocity penalty Δv_i is adequately approximated with a quadratic curve fit of the form

$$\Delta v_i = c_1 i^2 + c_2 i + c_3 . \tag{78}$$

Given a reference orbit inclination i and a circular orbit speed v_o, the velocity penalty Δv_g associated with a non-coplanar departure from this circular orbit to the desired hyperbolic excess velocity at a declination δ is defined as follows. Assuming the line of nodes of this reference orbit is an open variable, one may choose this variable to minimize the angle between the excess velocity and the orbital plane. This minimum angle is $\delta - i$. Gunther [5] has shown that the minimum incremental velocity required to achieve a given $v_{\infty o}$ along an asymptote not lying in the orbital plane from a specified circular orbit is obtained from the solution to a quartic equation in the sine of the out-of-plane angle. Defining

$$\begin{aligned} & s = \sin(\delta - i); \; \rho = v_{\infty o}/v_o ; \\ & p = s^2 (\rho^2 + 4); \end{aligned} \tag{79}$$

$$q = s^2 (1 - s^2) \rho^2;$$

$$x = \left[\sqrt{(q/2)^2 + (p/3)^3} + q/2\right]^{1/3} - \left[\sqrt{(q/2)^2 + (p/3)^3} - q/2\right]^{1/3};$$

$$y = \sqrt{\rho^2/4 - x}\,; \tag{79 (cont)}$$

$$w = \frac{1}{2}\left[\rho/2 + y + \sqrt{(\rho/2 + y)^2 + 4\left(x/2 + \sqrt{x^2/4 + s^2}\right)}\ \right],$$

then Gunther's solution for the magnitude of the minimum velocity impulse required to accomplish this maneuver is

$$v_g = v_o \sqrt{\rho^2 + 3 - 2\sqrt{(1 + \rho w - w^2)(2 + \rho w)}}\ , \tag{80}$$

and the penalty Δv_g is the difference between v_g and the velocity increment required if the out-of-plane angle were zero, i.e.,

$$\Delta v_g = v_g - \left(\sqrt{v_{\infty o}^2 + 2v_o^2} - v_o\right). \tag{81}$$

Thus, the definition of the characteristic speed for those cases in which the asymptote declination lies outside the interval [-i, i] is

$$v_c = \sqrt{v_{\infty o}^2 + 2v_o^2} + \Delta v_i + \Delta v_g = v_o + v_g + \Delta v_i\,. \tag{82}$$

The transversality conditions to be developed later define the optimum choices of δ, i, and the geocentric right ascension α of the excess velocity. Once these are known it is necessary to evaluate $V_{\infty o}$ in the ecliptic Cartesian coordinate system. This vector is evaluated

$$V_{\infty o} = v_{\infty o} \Phi^T \begin{bmatrix} \cos\alpha \cos\delta \\ \sin\alpha \cos\delta \\ \sin\delta \end{bmatrix}, \tag{83}$$

where Φ is the transformation matrix,

$$\Phi = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\epsilon & -\sin\epsilon \\ 0 & \sin\epsilon & \cos\epsilon \end{bmatrix}, \tag{84}$$

and ϵ is the obliquity of the ecliptic. A more complete development of this formulation, with examples, is given in Reference [6].

At intermediate targets, the mass ratio may be discontinuous to account for mass drops and sample pick-ups. Since these mass components are defined to be proportional to the initial mass, the mass ratio discontinuity is

$$\Delta\nu_i = \nu_i^+ - \nu_i^- = k_{\text{samp}\,i} - k_{\text{drop}\,i}\,. \tag{85}$$

Position and velocity at intermediate targets are continuous. The intercept of an intermediate target is achieved by imposing a constraint on the position error. At the i^{th} target, this constraint may be written

$$\Delta R_i = R_i - P_i = 0. \tag{86}$$

One may optionally constrain the passage speed $v_{\infty i}$ at an intermediate target. The constraint equation for this is

$$\Delta\dot{R}_i = \dot{R}_i - \dot{P}_i - V_{\infty i} = 0. \tag{87}$$

The direction of $V_{\infty i}$ is optimized.

In simulations of trajectories which are all-ballistic, the program is capable of simulating a single deep-space burn, or impulsive velocity-change, at any point prior to arrival at the primary target. The three components of the incremental velocity ΔV are independent variables of the boundary value problem, such that, at a specified time, the spacecraft velocity is incremented:

$$\dot{R}^{+} = \dot{R}^{-} + \Delta V \,. \tag{88}$$

The use of this program option is described in the Sample Problems and Results section under Sample Case H, Multiple Ballistic Swingby Mission.

In the HILTOP program, stopover missions having optimum stopover time are simulated simply by forcing the spacecraft to rendezvous with the desired intermediate target. If the trajectory segment immediately following the intermediate-target arrival-time begins with a coast phase, then the duration of that coast phase is the optimum stopover time. If that trajectory segment begins with a thrust phase, then the optimum stopover time is zero. To simulate a stopover mission having a specified stopover time, as in Sample Case E displayed later in this document, the same intermediate target should be specified twice consecutively, and of course the spacecraft should be forced to rendezvous with the intermediate target at the first encounter. Then inputting values for Λ and $\dot{\Lambda}$ at the start of the stopover trajectory segment (as boundary value problem independent variables) to be relatively small with respect to the mass ratio multiplier λ_{ν} will force the thrust switch function to be negative and cause the spacecraft to coast along with the intermediate target until the desired departure time is encountered*. In this manner the trajectory block print and extrema of selected functions are available during the stopover phase.

The capability is provided for constraining the total flight time of the mission (not including the flight time of the optional ballistic swingby-continuation trajectory segment). This feature is particularly useful in problems for which the analytic ephemeris is employed and for which the launch and (final) arrival dates are optimized but flight time is specified. The end condition is written

$$t_f = t_n - t_o \,, \tag{89}$$

where t_f is the specified total flight time and t_o and t_n are the launch and (final) arrival dates, respectively.

*Or, alternately, an imposed coast phase may be employed.

The capability for constraining propulsion time is implemented through satisfaction of the optional end condition,

$$\tau_f = \int_{t_o}^{t_n} h_\sigma \, dt \tag{90}$$

where h_σ is the step function defined in Section A and τ_f is the desired propulsion time. It should be noted that this constraint is an equality constraint; that is, if invoked, the propulsion time is forced to be equal to the input value (after convergence is achieved) regardless of whether this input value is less than or greater than the optimum propulsion time. Given a solution for constrained propulsion time, one can easily determine whether this propulsion time is less than or greater than the optimum value by the sign of the associated adjoint variable, λ_τ. A negative value of λ_τ indicates the constrained propulsion time is less than optimum whereas a positive value of λ_τ indicates the constrained propulsion time is greater than optimum.

Several spacecraft parameters are available as constraints. These are the net spacecraft mass, m_{net}, the intermediate target drop and sample masses, $m_{drop\,i}$ and $m_{samp\,i}$, respectively, and the reference power, p_{ref}. The equations employed in computing these two parameters are given in preceding sections, Spacecraft Mass Components and Electric Propulsion System, respectively.

All trajectories are integrated forward from the launch date t_o and are terminated at the time $(t_n - t_o)$ later. Primary-target conditions are computed using the variables evaluated at this trajectory termination time. For multiple-target missions in which intermediate targets are present, the integration is interrupted at intermediate times t_i and appropriate quantities are stored for the computation of dependent conditions.

4. Transversality Conditions. The application of the indirect method of optimization leads to a set of necessary conditions, some of which are known as

transversality conditions, that must be satisfied by the solution. In essence, for every boundary condition left open* in the problem posed, the indirect method provides a transversality condition. For a given performance index π which is to be minimized, the general equation for the transversality conditions is written

$$k\,d\pi + \sum_{i=1}^{n} \Big[\Lambda \cdot d\dot{R} - \dot{\Lambda} \cdot dR + \lambda_{\nu}\, d\nu + \lambda_{g}\, dg + \lambda_{c}\, dc + \lambda_{\phi}\, d\phi + \lambda_{\tau}\, d\tau - h_{v}\, dt\Big]_{t_{i-1}}^{t_i} = 0\,. \tag{91}$$

The convenient choice is made whereby λ_g, λ_c, and λ_ϕ are forced to be continuous at each intermediate target, which means that, for example, only $\lambda_g(t_n)$ need appear in the derived transversality expressions rather than the cumbersome expression

$$\lambda_g(t_n) - \sum_{i=1}^{n-1} (\lambda_g^{+}(t_i) - \lambda_g^{-}(t_i)) - \lambda_g(t_o).$$

This is because $\lambda_g(t_n)$ alone, with $\lambda_g(t_o) = 0$ and $\lambda_g^{+}(t_i) = \lambda_g^{-}(t_i)$ for each i, has the same value as the cumbersome expression cited above if $\lambda_g(t_o)$ were not zero and $\lambda_g(t_i)$ were not continuous, and this is due to the absence of λ_g in the differential equations, the same being true for λ_c and λ_ϕ. The scalar k is an arbitrary positive constant which expresses the arbitrariness of the performance index; in other words, the minimization of π is equivalent to the minimization of 2π, 3π, ..., etc. k effectively renders the general transversality condition linear and homogeneous in the adjoint variables, thus allowing the elimination of one terminal condition from the problem by appropriate choice of a value for k. Due to the independence of an unconstrained boundary condition, its differential is arbitrary, forcing its coefficient to vanish independently of all other terms in the equation and thereby yielding the desired transversality condition.

In the program HILTOP, all available transversality conditions are derived for the problem of maximizing net spacecraft mass, i.e., $\pi = - m_{net}$. From the

*The terminology "open" is synonymous with unspecified and "fixed" is synonymous with specified. An open parameter is generally optimized. Also, final time refers to time at the primary target.

earlier definition of m_{net}, one may write

$$\pi = j_r m_{rs} + m_o \Big\{ k_s + k_t - (1+k_t)\nu_n + j_r (1+k_{rt}) e_x \Big[(1 + j_t k_t)\nu_n - j_t k_t \Big(1 + \sum_{i=1}^{n-1} (k_{samp\,i} - k_{drop\,i})\Big)\Big] + (1+k_t) \sum_{i=1}^{n-1} k_{samp\,i} - k_t \sum_{i=1}^{n-1} k_{drop\,i} \Big\} + m_{ps} \Big[1 - j_r j_{ps} (1+k_{rt}) e_x \Big], \tag{92}$$

where j_r is a constant equal to one if a retro stage is employed and equal to zero otherwise. For the launch vehicle dependent formulation, m_o is a function only of the launch excess speed $v_{\infty o}$ and possibly the geocentric declination δ and launch parking orbit inclination i, and m_{ps} is evaluated

$$m_{ps} = \alpha p_{ref} = \alpha g\, c\, m_o / 2\eta, \tag{93}$$

where

$$\alpha = \alpha_t + (1 + \Delta p)\, \alpha_a.$$

Of course, if reference power is constrained in this formulation, then m_{ps} is fixed, and only two of the three parameters g, c, and m_o are independent. On the other hand, for the launch vehicle independent formulation the reference power (and therefore m_{ps}) is always fixed and m_o is obtained directly from the equation,

$$m_o = 2\eta p_{ref} / gc, \tag{94}$$

such that m_o is functionally dependent upon g and c. Thus π may be written functionally in its most general form,

$$\pi = \pi(v_{\infty o},\ v_{\infty n},\ \nu_n,\ g,\ c,\ \delta,\ i). \tag{95}$$

Consequently, using the notation $\pi_x = \partial \pi / \partial x$, one obtains

$$d\pi = \pi_{v_{\infty o}} dv_{\infty o} + \pi_{v_{\infty n}} dv_{\infty n} + \pi_{\nu_n} d\nu_n + \pi_g dg + \pi_c dc + \pi_\delta d\delta + \pi_i di . \tag{96}$$

To write the partial derivatives indicated, it is convenient to first define a factor, j_p, which is equal to zero if reference power is fixed and equal to one otherwise. Also, employing the notation of earlier sections, define

$$g_x = j_r e_x (1 + k_{rt})\left[1 + \frac{4c_1 f_x (1 - e_x)}{2c_r - c_1 (f_x - e_x)^2}\right], \tag{97}$$

(where g_x is a new symbol similar to e_x and f_x) and note that

$$\pi_{m_o} = \frac{\partial \pi}{\partial m_o} = k_s + k_t + j_p \frac{\alpha g c}{2\eta} - (1 + k_t)\nu_n + (1 + k_t)\sum_{i=1}^{n-1} k_{samp\,i}$$
$$- k_t \sum_{i=1}^{n-1} k_{drop\,i} + g_x\left[(1 + j_t k_t)\nu_n - j_t k_t (1 + \sum_{i=1}^{n-1} (k_{samp\,i} - k_{drop\,i}))\right.$$
$$\left. - j_p j_{ps} \frac{\alpha g c}{2\eta}\right]. \tag{98}$$

Then one may write the indicated partial derivatives of π as follows for the launch vehicle dependent formulation:

$$\pi_{v_{\infty o}} = \pi_{m_o} \frac{\partial m_o}{\partial v_{\infty o}} , \tag{99}$$

$$\pi_{v_{\infty n}} = j_r \frac{2(m_o \nu_n - j_t m_t - j_{ps} m_{ps})(1 + k_{rt})(1 - e_x) v_{\infty n}}{(v_{\infty n}^2 + 2v_c^2)^{\frac{1}{2}}[2c_r - c_1 (f_x - e_x)^2]} \left[1 + \frac{2c_1 e_x f_x v_c^2}{(v_{\infty n}^2 + v_c^2)(v_{\infty n}^2 + 2v_c^2)^{\frac{1}{2}}}\right], \tag{100}$$

$$\pi_{\nu_n} = m_o [g_x (1 + j_t k_t) - (1 + k_t)] , \tag{101}$$

$$\pi_g = j_p \frac{m_{ps}}{g} (1 - j_{ps} g_x) , \tag{102}$$

$$\pi_c = j_p \frac{m_{ps}}{c}\left(1 - \frac{c\eta'}{\eta}\right)\left(1 - j_{ps} g_x\right) , \tag{103}$$

$$\pi_\delta = \pi_{m_o} \frac{\partial m_o}{\partial \delta} , \tag{104}$$

$$\pi_i = \pi_{m_o} \frac{\partial m_o}{\partial i} , \tag{105}$$

where $\eta' = d\eta/dc$ and

$$\begin{aligned}
\frac{\partial m_o}{\partial v_{\infty o}} &= \frac{dm_o}{dv_c} \frac{\partial v_c}{\partial v_{\infty o}} , \\
\frac{\partial m_o}{\partial \delta} &= \frac{dm_o}{dv_c} \frac{\partial v_c}{\partial \delta} , \\
\frac{\partial m_o}{\partial i} &= \frac{dm_o}{dv_c} \frac{\partial v_c}{\partial i} , \\
\frac{dm_o}{dv_c} &= -(b_1/b_2)\, e^{-(v_c/b_2)} .
\end{aligned} \tag{106}$$

The forms of the derivatives $\partial v_c/\partial v_{\infty o}$, $\partial v_c/\partial \delta$ and $\partial v_c/\partial i$ depend on the definition of v_c. For relatively small geocentric declinations of $V_{\infty o}$, v_c is given by equation (3). Then

$$\begin{aligned}
\frac{\partial v_c}{\partial v_{\infty o}} &= \frac{v_{\infty o}}{v_c} , \\
\frac{\partial v_c}{\partial \delta} &= 0 , \\
\frac{\partial v_c}{\partial i} &= 0 .
\end{aligned} \tag{107}$$

In the high-declination case where v_c includes the penalties due to launch azimuth and non-coplanar injection, the derivatives are considerably more complex. The formulas for the derivatives of v_c with respect to the three independent parameters $v_{\infty o}$, δ and i are

$$\frac{\partial v_c}{\partial v_{\infty o}} = \frac{\partial v_g}{\partial v_{\infty o}} ,$$

$$\frac{\partial v_c}{\partial \delta} = \frac{\partial v_g}{\partial \delta} , \tag{108}$$

$$\frac{\partial v_c}{\partial i} = \frac{\partial v_g}{\partial i} + \frac{\partial \Delta v_i}{\partial i} ,$$

where, from (78)

$$\partial \Delta v_i / \partial i = 2 c_1 i + c_2 , \tag{109}$$

and, from (79) and (80),

$$\partial v_g / \partial i = - \partial v_g / \partial \delta . \tag{110}$$

The derivation of the partial derivatives $\partial v_g / \partial v_{\infty o}$ and $\partial v_g / \partial \delta$ is straightforward although somewhat cumbersome. The equations for these partial derivatives,employing the notation defined earlier, are as follows:

$$\frac{\partial v_g}{\partial v_{\infty o}} = \frac{v_o^2}{v_g} \left\{ \rho \frac{\partial \rho}{\partial v_{\infty o}} - \frac{w(3+2\rho w-w^2)(\partial \rho / \partial v_{\infty o})+(3\rho+2\rho^2 w-3\rho w^2 - 4w)(\partial w / \partial v_{\infty o})}{2\sqrt{(1+\rho w - w^2)(2+\rho w)}} \right\} , \tag{111}$$

$$\frac{\partial v_g}{\partial \delta} = - \frac{v_o^2 (3\rho + 2\rho^2 w - 3\rho w^2 - 4w)}{2 v_g \sqrt{(1+\rho w - w^2)(2+\rho w)}} \frac{\partial w}{\partial \delta} , \tag{112}$$

where

$$\partial \rho / \partial v_{\infty o} = 1/v_o , \tag{113}$$

$$\frac{\partial w}{\partial v_{\infty o}} = \frac{1}{2}\left\{\frac{1}{2}\,\frac{\partial \rho}{\partial v_{\infty o}} + \frac{\partial y}{\partial v_{\infty o}} + \left[\left(1 + \frac{x}{2\sqrt{x^2/4+s^2}}\right)\frac{\partial x}{\partial v_{\infty o}} + \left(\frac{\rho}{2}+y\right)\left(\frac{1}{2}\,\frac{\partial \rho}{\partial v_{\infty o}}\right.\right.\right.$$

$$\left.\left.\left. + \frac{\partial y}{\partial v_{\infty o}}\right)\right]/(2w - \rho/2 - y)\right\}, \tag{114}$$

$$\frac{\partial w}{\partial \delta} = \frac{1}{2}\left\{\frac{\partial y}{\partial \delta} + \left[\frac{\partial x}{\partial \delta} + \frac{x(\partial x/\partial \delta)+4s(\partial s/\partial \delta)}{2\sqrt{x^2/4+s^2}} + \left(\frac{\rho}{2}+y\right)\frac{\partial y}{\partial \delta}\right]/(2w-\rho/2-y)\right\}, \tag{115}$$

$$\partial s/\partial \delta = \cos\ (\delta - i), \tag{116}$$

$$\partial y/\partial v_{\infty o} = \left[(\rho/2)\,\partial \rho/\partial v_{\infty o} - \partial x/\partial v_{\infty o}\right]/2y, \tag{117}$$

$$\partial y/\partial \delta = -\ (\partial x/\partial \delta)/2y, \tag{118}$$

$$\frac{\partial x}{\partial u} = \frac{1}{6}\left[\frac{(q/2)(\partial q/\partial u) + (p/3)^2(\partial p/\partial u)}{\sqrt{(q/2)^2 + (p/3)^3}} + \frac{\partial q}{\partial u}\right]\left[\sqrt{(q/2)^2 + (p/3)^3} + q/2\right]^{-2/3}$$

$$- \frac{1}{6}\left[\frac{(q/2)(\partial q/\partial u) + (p/3)^2(\partial p/\partial u)}{\sqrt{(q/2)^2 + (p/3)^3}} - \frac{\partial q}{\partial u}\right]\left[\sqrt{(q/2)^2 + (p/3)^3} - q/2\right]^{-2/3}, \tag{119}$$

with $u = v_{\infty o}$ or δ,

$$\partial q/\partial v_{\infty o} = 2\,\rho s^2\,(1 - s^2)(\partial \rho/\partial v_{\infty o})\ , \tag{120}$$

$$\partial q/\partial \delta = 2\rho^2 s\,(1 - 2s^2)(\partial s/\partial \delta), \tag{121}$$

$$\partial p/\partial v_{\infty o} = 2\,\rho s^2\ (\partial \rho/\partial v_{\infty o}), \tag{122}$$

$$\partial p/\partial \delta = 2s\ (\rho^2 + 4)(\partial s/\partial \delta). \tag{123}$$

For the launch vehicle independent formulation, the partials $\pi_{v_{\infty n}}$ and π_{ν_n} remain unchanged from expressions (100) and (101). The remaining partials become,

$$\pi_{v_{\infty o}} = \pi_\delta = \pi_i = 0 , \tag{124}$$

$$\pi_g = -\frac{m_o}{g} \pi_{m_o} , \tag{125}$$

$$\pi_c = -\frac{m_o}{c}\left(1 - \frac{c\,\eta'}{\eta}\right)\pi_{m_o} . \tag{126}$$

Of course, for the launch vehicle independent formulation, the factor j_p is always taken to be zero, since a condition of the formulation is that reference power is fixed.

Now, consider the differentials dR and $d\dot{R}$ at the initial and final times. At launch

$$dR_o = dP_o = \dot{P}_o \, dt_o , \tag{127}$$

$$d\dot{R}_o = d\dot{P}_o + dV_{\infty o} = \ddot{P}_o dt_o + dV_{\infty o} . \tag{128}$$

The differential $dV_{\infty o}$ may be written in terms of differentials in its magnitude and any two arbitrary, but independent, angles which would uniquely define the orientation of $V_{\infty o}$. Because of its importance in the formulation, one of these angles will be chosen to be the geocentric declination, δ. For convenience, the other is chosen to be the geocentric right ascension, α. In terms of these angles, $dV_{\infty o}$ may be written

$$dV_{\infty o} = \frac{V_{\infty o}}{v_{\infty o}} dv_{\infty o} + (\bar{n}_p \times V_{\infty o}) d\alpha + [(V_{\infty o} \times \bar{n}_p) \times V_{\infty o}/v_{\infty o} \cos\delta] d\delta , \tag{129}$$

where $\bar{n}_p$ is a unit vector in the direction of the Earth's North Pole.

At the primary target the form of the differentials will vary according to the target condition option chosen. For the ephemeris option

$$dR_n = \dot{P}_n \, dt_n \, , \tag{130}$$

and, providing the velocity at arrival is not left completely open,

$$d\dot{R}_n = \ddot{P}_n \, dt_n + dV_{\infty n} \, . \tag{131}$$

As above for $dV_{\infty o}$, we may choose any two independent angles, say α_1 and α_2, and the magnitude $v_{\infty n}$ as a set of three parameters uniquely defining $V_{\infty n}$, and $dV_{\infty n}$ may then be written

$$dV_{\infty n} = \frac{V_{\infty n}}{v_{\infty n}} \, dv_{\infty n} + (\bar{a}_1 \times V_{\infty n}) \, d\alpha_1 + (\bar{a}_2 \times V_{\infty n}) \, d\alpha_2 \, , \tag{132}$$

where $\bar{a}_1$ and $\bar{a}_2$ are unit vectors normal to the planes in which α_1 and α_2, respectively, are measured.

For the open angle transfer option, the fixed final solar distance gives rise to the scalar equation,

$$R_n \cdot dR_n = 0 \, , \tag{133}$$

and, if the final orbit is constrained to be circular,

$$d\dot{R}_n = \sqrt{\frac{\mu}{r_n^3}} \, (\bar{k} \times dR_n) + dV_{\infty n} \, , \tag{134}$$

with the expression for $dV_{\infty n}$ being as given above. For the extra-ecliptic option, it may be recalled that the final radius, speed, inclination to the ecliptic, and flight path angle are fixed. Optionally, the semi-major axis, eccentricity and inclination may be fixed. It is therefore convenient to write the differentials of position and velocity in terms of the two or three non-vanishing differentials $d\Omega_n$, $d\omega_n$, and, when applicable, df_n, where f_n is the final true anomaly. These are,

$$dR_n = (\bar{k} \times R_n) \, d\Omega_n + (\bar{h} \times R_n)(d\omega_n + df_n) \, , \tag{135}$$

$$d\mathring{R}_n = (\bar{k} \times \mathring{R}_n)\, d\Omega_n + (\bar{h} \times \mathring{R}_n)(d\omega_n + df_n), \tag{136}$$

where $\bar{h}$ is a unit vector along the final angular momentum $R_n \times \mathring{R}_n$.

At intermediate targets, the differential of the position vector is

$$dR_i = dP_i = \mathring{P}_i\, dt_i , \tag{137}$$

while, for the velocity vector,

$$d\mathring{R}_i = d\mathring{P}_i + dV_{\infty i} = \ddot{P}_i\, dt_i + dV_{\infty i} . \tag{138}$$

As above for $dV_{\infty o}$ and $dV_{\infty n}$, we write $dV_{\infty i}$ as follows

$$dV_{\infty i} = \frac{V_{\infty i}}{v_{\infty i}}\, dv_{\infty i} + (\bar{a}_{i1} \times V_{\infty i})\, d\alpha_{i1} + (\bar{a}_{i2} \times V_{\infty i})\, d\alpha_{i2} . \tag{139}$$

Other optional constraints which result in variations in the form of the transversality conditions are the flight time, which results in

$$dt_n = dt_o , \tag{140}$$

and the reference power, p_{ref}, which yields,

$$\frac{dg}{g} + \left(\frac{1}{c} - \frac{\eta'}{\eta}\right) dc + \frac{dm_o}{m_o} = 0 , \tag{141}$$

where, in its most general form,

$$dm_o = \frac{\partial m_o}{\partial v_c}\left(\frac{\partial v_c}{\partial v_{\infty o}}\, dv_{\infty o} + \frac{\partial v_c}{\partial \delta}\, d\delta + \frac{\partial v_c}{\partial i}\, di\right) . \tag{142}$$

Finally, the fact that the initial mass ratio is always taken to be unity yields the result,

$$d\nu_o = 0 . \tag{143}$$

The constraint equations (in differential form) are employed to eliminate from the general transversality equation (91) a like number of differentials. Requiring that the coefficients of the remaining differentials vanish provides the appropriate set of transversality conditions for a specific problem. However, because the adjoint equations are linear and homogeneous in the adjoint variables, it is possible to fix the initial value of one of the adjoint variables. It is convenient to choose the initial mass ratio multiplier λ_{ν_o} as the independent parameter to be held constant, and choosing a value of unity will generally result in initial values of the other adjoint variables also of order one. Also, the arbitrary positive performance index constant k in expression (91) will be assigned a value which causes the transversality condition associated with the final mass ratio to be satisfied;

$$k = \lambda_{\nu_n} / \pi_{\nu_n} \quad . \tag{144}$$

The choice of eliminating λ_{ν_o} from the boundary value problem independent parameters is made by the program user when the program inputs for a particular problem are composed. Indeed, it is sometimes, but not often, advantageous to not hold λ_{ν_o} fixed when attempting to obtain a converged solution to a particular problem. The choice of eliminating the final mass ratio transversality condition from the boundary value problem dependent conditions is made arbitrarily and is accomplished automatically by the internal coding within the program. These two choices reduce the order of the boundary value problem by one, which is considered to be advantageous in this particular instance (in terms of conserving computation time), even though it is not always advantageous to reduce the order of a boundary value problem, thereby forcing the boundary value problem onto a possibly highly nonlinear constraint subspace.

Once these choices are made, the appropriate transversality conditions may be derived and written as follows:

For open launch excess speed with m_o being independent of δ and i the

transversality condition is,

$$-\frac{k\pi_{v_{\infty o}}}{\lambda_o} - (1-j_p)\frac{g\lambda_g}{\lambda_o m_o}\frac{\partial m_o}{\partial v_{\infty o}} - 1 = 0 . \tag{145}$$

For open launch excess velocity direction with initial mass independent of δ and i:

$$\Lambda_o \times V_{\infty o} = 0. \tag{146}$$

This implies $V_{\infty o} \parallel \Lambda_o$; $V_{\infty o}$ aligned with Λ_o is usually the proper choice.

For cases in which m_o is a function of δ and/or i, the transversality conditions are modified as follows, where

$$f = [k_s + k_t - (1+k_t)\nu_n - g\lambda_g/km_o]\, dm_o/dv_c. \tag{147}$$

Open excess speed:

$$f(\partial v_g/\partial v_{\infty o}) - (\Lambda_o \cdot V_{\infty o})/v_{\infty o} = 0 . \tag{148}$$

Open geocentric declination of $V_{\infty o}$:

$$f(\partial v_g/\partial \delta) - \Lambda_o \cdot [(V_{\infty o} \times \bar{n}_p) \times V_{\infty o}/v_{\infty o} \cos\delta] = 0 . \tag{149}$$

Open right ascension of $V_{\infty o}$:

$$-\Lambda_o \cdot (\bar{n}_p \times V_{\infty o}) = 0 . \tag{150}$$

Open launch parking orbit inclination:

$$f(\partial \Delta v_i/\partial i - \partial v_g/\partial \delta) = 0. \tag{151}$$

Note that these last two equations are functions only of initial conditions*; hence, they may be solved directly for α and i, which therefore need not be included explicitly as independent parameters. Equation (150) dictates that α be equated to the geocentric

*Assuming $f \neq 0$.

right ascension of Λ_o, or 180 degrees therefrom. Equation (151) may be solved for i; however, the expressions are sufficiently complex that the solution must be obtained iteratively.

For open excess velocity direction at an intermediate target, the condition is,

$$(\Lambda_i^+ - \Lambda_i^-) \times V_{\infty i} = 0. \tag{152}$$

For open excess speed at an intermediate target, the primer is continuous, i.e.,

$$\Lambda_i^+ - \Lambda_i^- = 0. \tag{153}$$

For open excess velocity direction at the final target, the transversality condition is

$$\Lambda_n \times V_{\infty n} = 0. \tag{154}$$

The proper direction of $V_{\infty n}$ is usually opposite Λ_n.

For open arrival excess speed (at the primary target) in problems where a retro stage is employed, the transversality condition is,

$$- \frac{k\pi_{v_{\infty n}}}{\lambda_n} - 1 = 0 . \tag{155}$$

For open thrust acceleration with unspecified reference power in the launch vehicle dependent formulation, the transversality condition is,

$$- \frac{k\pi_g}{\lambda_g} + 1 = 0. \tag{156}$$

For open jet exhaust speed with unspecified reference power in the launch vehicle dependent formulation, the transversality condition is,

$$- \frac{k\pi_c}{\lambda_c} + 1 = 0 . \tag{157}$$

These last two equations also apply for open thrust acceleration and open jet exhaust speed, respectively, in the launch vehicle independent formulation with fixed reference power. Of course, the appropriate expressions for the partials of π must be used, however.

If the reference power is specified using the launch vehicle dependent formulation, but both reference thrust acceleration and jet exhaust speed are left open, the last two transversality conditions are replaced in favor of the one condition,

$$1 - \frac{\lambda_g}{\lambda_c} \frac{g}{c} \left(1 - \frac{c\eta'}{\eta}\right) = 0. \tag{158}$$

In the preceding equations λ_g and λ_c are evaluated at time t_n, the time at which the spacecraft is to be at the primary target. When using the open angle transfer option, the transversality condition associated with the open angle is

$$\left[\dot{\Lambda}_n \times R_n - \Lambda_n \times \dot{R}_n\right] \cdot \bar{k} = 0. \tag{159}$$

For either the ephemeris or open angle options, if the final velocity is completely unspecified, as in the case of flyby missions, the appropriate vector transversality condition is,

$$\Lambda_n = 0. \tag{160}$$

This causes the primer locus (trajectory in primer-space) to home-in on the origin of primer-space, which is a singularity of the optimal rocket problem (as previously mentioned) if the spacecraft should be thrusting at that point. However, if forced-thrusting is not invoked via the propulsion-time multiplier λ_τ, condition (160) tends to cause a coast phase to occur at the time of flyby, thus avoiding the singularity. A similar situation can occur at the initial time for the launch vehicle independent mode if launch excess speed is to be optimized. This leads to the condition

$$\Lambda_o = 0. \tag{161}$$

For the extra-ecliptic option, the fact that Ω and ω are left open in specifying the final state gives rise to the two conditions,

$$C \cdot \bar{k} = 0 , \tag{162}$$

$$C \cdot \bar{h} = 0, \tag{163}$$

where $C = R_o \times \mathring{\Lambda}_o - \mathring{R}_o \times \Lambda_o$ is the vector constant of the motion on a given trajectory segment and $\bar{h}$ is a unit vector along the angular momentum of the final heliocentric orbit. If the option is employed which additionally leaves final true anomaly open, the extra condition,

$$\frac{\mu}{r}(\Lambda \cdot R) + r^2 (\mathring{\Lambda} \cdot \dot{R}) = 0 , \tag{164}$$

applies. The transversality condition associated with open launch date for the ephemeris option is,

$$- \Lambda_o \cdot \ddot{P}_o + \mathring{\Lambda}_o \cdot \dot{P}_o + h_{vo} = 0, \tag{165}$$

the condition for open encounter date at an intermediate target is,

$$- (\Lambda_i^+ - \Lambda_i^-) \cdot \ddot{P}_i + (\dot{\Lambda}_i^+ - \dot{\Lambda}_i^-) \cdot \mathring{P}_i + h_{vi}^+ - h_{vi}^- = 0, \tag{166}$$

while the appropriate condition for open arrival date (at the primary target) with the ephemeris option is,

$$\Lambda_n \cdot \ddot{P}_n - \dot{\Lambda}_n \cdot \dot{P}_n - h_{vn} = 0. \tag{167}$$

Since the variational Hamiltonian h_v is a constant of the motion on a given trajectory segment, the time at which it is evaluated on that segment is arbitrary. The preceding conditions pertaining to initial and final time are applicable if the total flight time is unconstrained. In the event that the total flight time is fixed while both t_o and t_n are left open, the two preceding conditions are replaced with the single condition represented by the sum of the two, i.e.,

$$\Lambda_n \cdot \ddot{P}_n - \dot{\Lambda}_n \cdot \dot{P}_n - h_{vn} - \Lambda_o \cdot \ddot{P}_o + \dot{\Lambda}_o \cdot \dot{P}_o + h_{vo} = 0. \tag{168}$$

For either the open angle or extra ecliptic options, the appropriate transversality condition associated with open arrival date (i.e., open flight time) is

$$- h_v = 0 , \tag{169}$$

where the signs (+ and -) in all the preceding expressions are displayed as they are coded in the program.

Finally, the transversality condition associated with unspecified, but constant, thrust cone angle is,

$$\lambda_\phi (t_n) = 0. \tag{170}$$

5. Partial Derivatives. In solving the two-point boundary-value problem, the finite difference method is used for computing the required matrix of partial derivatives of the dependent variables (i.e., end conditions or constraints) with respect to the independent variables. The finite difference method involves individually perturbing each independent variable x_i to be optimized and computing an associated perturbed dependent parameter vector Y_p. The amount each independent parameter is perturbed, Δx_i, is specified by program input. The desired partial derivatives are then approximated as follows:

$$P = \frac{\partial Y}{\partial x_i} = \frac{Y_p - Y}{\Delta x_i} , \tag{171}$$

where Y represents the nominal dependent parameter vector. The finite difference method is completely general and is applicable to all end condition options available in the program.

C. EXTENSION OF SOLUTION FOR POWER DEGRADATION.

The assumed spacecraft and trajectory models are as described earlier in Section A and are not repeated here; the nomenclature used in the following analysis is also described in Section A, except for the introduction of new symbols which are described in the text as they appear.

Historically, this electric propulsion power degradation model first appeared in the literature in [7], and then soon afterward an improved discussion appeared in [8], in which several of the ramifications and consequences of the theory are also discussed. For deeper insight into the analysis, the reader is therefore referred to [8], from which much of the analysis below is extracted.

The model discussed here is concerned with the manner in which the performance of a solar array degrades due to high energy particle damage. It is assumed that one can define a damage factor q which has a value of unity at the initial time and which decreases in value with time during the course of the mission such that the power output, p, of the arrays at any time may be written

$$p = q \gamma p_{ref} , \tag{172}$$

where p_{ref} is the reference power and γ is the power factor which is a function of solar distance and array orientation relative to the sun. The damage factor q may also be thought of as a time-dependent efficiency. The derivative $\dot{q}$ is negative, and is assumed to be linearly proportional to q and to the density of particles impinging on the solar cells. For simplicity, it is assumed that the particle density d is of the same form as the density of photons striking the surface of the array, i.e.,

$$d = \frac{\bar{e}_r \cdot \bar{n}}{r^2} , \tag{173}$$

where $\bar{e}_r$ is a unit vector along the sun-spacecraft line, $\bar{n}$ is a unit vector normal to the arrays such that $\bar{e}_r \cdot \bar{n} > 0$ implies the front of the panels faces the sun, and

r is the solar distance of the spacecraft. Then

$$\dot{q} = -kqd, \tag{174}$$

and

$$q = e^{-k\int_0^t d\,dt'}, \tag{175}$$

where k is the constant of proportionality. It is convenient to introduce a parameter s, called degradation time,

$$s = \int_0^t d\,dt', \tag{176}$$

or

$$\dot{s} = d. \tag{177}$$

Thus, under the above assumptions the degradation time accumulates at a faster rate when the spacecraft is nearer the sun, which is a characteristic one might expect. Note that when the spacecraft is maintained at 1 AU with the panels normal to the sun line, $\dot{s} = 1$ and the degradation time is equal to the flight time. Then k may conveniently be thought of as the inverse of a reference time, called the characteristic degradation time denoted by τ_d, and the degradation factor q becomes

$$q = e^{-s/\tau_d}. \tag{178}$$

Actually, there is little reason to allow the degradation time s to continue to accumulate during coast phases since the arrays may be turned edgewise to the sun and the degradation process may be effectively halted. Therefore, we adjust equation (177) to read

$$\dot{s} = h_\sigma d, \tag{179}$$

where h_σ is a step function equal to one during thrust phases and equal to zero during coast phases.

The characteristic degradation time τ_d is an engineering parameter that must be determined experimentally. For example, by exposing a solar cell to

the particle emission of a solar simulator and measuring the performance of the cell over a period of time, one should be able to estimate a reasonable value of τ_d. Another source of information would be measurements from actual spacecraft which employ solar cells for power supply.

The assumed exponential form of the degradation factor, although intended for use with SEP systems, is applicable for NEP systems as well. The principal difference is in the definition of $\dot{s}$; for example, $\dot{s} = h_\sigma$. The exponential form also permits one to evaluate radio-isotope systems by defining $\dot{s} = 1$ and letting τ_d represent the time for the radioactivity to dissipate to $1/e$ of its initial level.

In the development which follows, the formulation applicable to SEP is used exclusively. The equations of motion and adjoint equations are given in Section A; the equations affected by the inclusion of power degradation in the model are given below.

Power degradation affects the problem in a very fundamental sense, beginning with the rocket-thrust term in the equations of motion:

$$\dot{V} = \ddot{R} = a\bar{e}_t - \frac{\mu}{r^3} R , \qquad \dot{R} = V , \tag{180}$$

where R is the position vector, r is the magnitude of R, V is the velocity vector, μ is the gravitational constant of the sun, a is the magnitude of the thrust acceleration and $\bar{e}_t$ is a unit vector in the direction of thrust. The thrust acceleration a is a function of several variables and may be written as follows:

$$a = h_\sigma \frac{g\gamma q}{\nu} , \tag{181}$$

where g is a reference thrust acceleration evaluated under a prescribed set of conditions, ν is the ratio of current to initial mass, and q is the degradation factor defined above. The power factor γ is assumed to be a function of the density, d,

of photons incident on the arrays, where d is as written in equation (173). The general form of γ is,

$$\gamma = d \sum_{i=0}^{4} a_i d^{i/4} . \tag{182}$$

The coefficients a_i are chosen so that this equation will adequately describe the power output of a given array. The only restriction of the a_i is that their sum is equal to one. Then at $r = 1$ AU, with the arrays normal to the sun line, $\gamma = d = 1$. The summation term in (182) represents the temperature effect.

The mass ratio satisfies the differential equation,

$$\dot{\nu} = - h_\sigma \frac{g \gamma q}{c} , \tag{183}$$

using $\nu = 1$ as an initial condition, where c is the jet exhaust speed which is assumed to be constant over the trajectory.

The variational Hamiltonian becomes,

$$\begin{aligned} h_v &= \Lambda \cdot \ddot{R} - \dot{\Lambda} \cdot \dot{R} + \lambda_\nu \dot{\nu} + \lambda_\tau \dot{\tau} + \lambda_s \dot{s} + \lambda_g \dot{g} + \lambda_c \dot{c} \\ &= h_\sigma \left[\frac{g\gamma q}{\nu} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu) + \lambda_s d + \lambda_\tau \right] - \frac{\mu}{r^3} (\Lambda \cdot R) - \dot{\Lambda} \cdot \dot{R}, \end{aligned} \tag{184}$$

and the adjoint equations are

$$\begin{aligned} \ddot{\Lambda} &= - \frac{\mu}{r^3} \Lambda + \frac{3\mu}{r^5} (R \cdot \Lambda) R + h_\sigma \left[\frac{g \gamma^* q}{\nu} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu) + \lambda_s \right] \frac{\partial d}{\partial R} , \\ \dot{\lambda}_\nu &= h_\sigma \frac{g\gamma q}{\nu^2} (\Lambda \cdot \bar{e}_t) , \\ \dot{\lambda}_g &= - h_\sigma \frac{\gamma q}{\nu} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu) , \end{aligned} \tag{185}$$

$$\dot{\lambda}_c = -h_\sigma \frac{g\gamma q}{c^2} \lambda_\nu ,$$

$$\dot{\lambda}_s = h_\sigma \frac{g\gamma q}{\nu\tau_d} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu) , \qquad (185) \text{ cont.}$$

where

$$\gamma^* = \partial\gamma/\partial d = \sum_{i=0}^{4} a_i \left(1+\frac{i}{4}\right) d^{i/4} ,$$

$$\frac{\partial d}{\partial R} = \frac{1}{r^3} \left[\bar{n} - 3(\bar{e}_r \cdot \bar{n})\, \bar{e}_r\right].$$

The control variables are the thrust direction $\bar{e}_t$, the switch step function h_σ, and, providing the array orientation is not constrained to yield maximum power, the normal direction $\bar{n}$. According to the Maximum Principle, these controls are chosen to maximize the variational Hamiltonian (184). The maximum of h_v with respect to h_σ is seen to depend totally on the sign of the term in square brackets. That is, denoting

$$\sigma^* = \frac{g\gamma q}{\nu} (\Lambda \cdot \bar{e}_t - \frac{\nu}{c} \lambda_\nu) + \lambda_s d + \lambda_\tau , \qquad (186)$$

then choose

$$h_\sigma = \begin{cases} 1 & \text{if } \sigma^* > 0 \\ 0 & \text{if } \sigma^* < 0 \end{cases} . \qquad (187)$$

Maximizing h_v with respect to $\bar{e}_t$ is also accomplished by inspection. Since $\bar{e}_t$ appears only in the dot product with Λ and since the coefficient of that dot product is non-negative, i.e.,

$$h_\sigma g\gamma q/\nu \geq 0 , \qquad (188)$$

then h_v is maximized with respect to $\bar{e}_t$ by making $\Lambda \cdot \bar{e}_t$ as large as possible, which is the same result as when there is no degradation. The control vector $\bar{n}$ appears explicitly in (184) through the density d as given by equation (173). In fact, since $\bar{n}$ appears in h_v only through d, $\bar{n}$ affects h_v only through its dot product with $\bar{e}_r$. Letting the angle between $\bar{n}$ and $\bar{e}_r$ be denoted χ such that

$\bar{e}_r \cdot \bar{n} = \cos \chi$, then it is clear that there will be a "best" angle χ between $\bar{n}$ and $\bar{e}_r$ to maximize h_v, but that $\bar{n}$ may lie along any element of a right circular cone of half angle χ about $\bar{e}_r$. For the moment, we will put aside the question of the explicit direction of $\bar{n}$ and concentrate on defining the optimum χ or, alternatively, the optimum d. The optimum value of d is determined by maximizing h_v with respect to d, i.e., by solving for the root of the equation

$$\frac{\partial h_v}{\partial d} = h_\sigma \frac{\partial \sigma^*}{\partial d} = 0 . \tag{189}$$

Performing the indicated differentiation yields

$$\frac{g \gamma^* q}{\nu} \sigma_r + \lambda_s = 0 , \tag{190}$$

or

$$\gamma^* = - \frac{\lambda_s \nu}{g q \sigma_r} , \tag{191}$$

where, using (182),

$$\gamma^* = \sum_{i=0}^{4} a_i (1 + \frac{i}{4}) d^{i/4} , \tag{192}$$

and

$$\sigma_r = \Lambda \cdot \bar{e}_t - \frac{\nu \lambda_\nu}{c} . \tag{193}$$

Because of the form of (192) equation (190) is a quartic in the variable $d^{i/4}$, and is solved by iteration in the program. A more detailed discussion of the solution to (190) is given in Reference [8] for a specific set of coefficients a_i. For now, assume that the optimum value of d is found from (190). Then the optimum angle χ is immediately obtained

$$\cos \chi = d r^2 . \tag{194}$$

Of course, equation (190) does not take into consideration the fact that d can never exceed the inverse square of the solar distance. Consequently, the right hand side of (194) may exceed unity, under which condition the program sets $\cos \chi \equiv 1$ (i.e.,

$\chi = 0$) implying that $\bar{n}$ is directed along $\bar{e}_r$.

If the d that represents the solution to (190) exceeds the upper limit allowed for d whether that limit is imposed by the problem or by nature (i.e., $1/r^2$), the correct choice for d is that upper-limiting value. Likewise, on the lower side, d is physically limited to be non-negative. Therefore, a negative solution to (190) is disregarded, and d is set to zero which corresponds to $\chi = \pi/2$ (panels oriented edgewise to the sun), and the engines are shut down.

The precise definition of $\bar{n}$ has no bearing on the solution of the problem, except as it affects d as defined in (173). The appearance of $\bar{n}$ in the state and adjoint equations and the variational Hamiltonian is solely through the density d except in the equation for $\ddot{\Lambda}$ where $\bar{n}$ appears explicitly as part of the partial $\partial d/\partial R$, defined following equations (185). Actually, this partial is valid only if d is permitted to vary with R. That is, if either $d = 0$ or $d = \text{constant}$ is imposed then $\partial d/\partial R$ becomes the null vector and the entire term drops from the equation for $\ddot{\Lambda}$. Furthermore, if d is the solution to (190), then the last term of $\ddot{\Lambda}$ in (185) again drops out because the term in square brackets is the left side of (190). Therefore, the only time the term in question remains in the equation for $\ddot{\Lambda}$ is when $d = 1/r^2$ which corresponds to $\cos\chi = \bar{e}_r \cdot \bar{n} = 1$ and implies $\bar{n} \equiv \bar{e}_r$. Under this condition

$$\frac{\partial d}{\partial R} = -\frac{2}{r^3}\,\bar{e}_r\,. \tag{195}$$

The boundary condition pertaining to the initial degradation time is

$$s(t_o) = 0\,. \tag{196}$$

If the final degradation time, s_n, is unspecified, the transversality condition associated with degradation time is

$$\lambda_{s_n} = 0. \tag{197}$$

The initial value of λ_s is unknown and therefore becomes one of the independent parameters of the boundary value problem. From equations (185), it follows that

$$\dot{\lambda}_s = -\frac{g}{\tau_d} \dot{\lambda}_g , \tag{198}$$

and, therefore,

$$\lambda_{s_n} - \lambda_{s_o} = -\frac{g}{\tau_d} (\lambda_{g_n} - \lambda_{g_o}) . \tag{199}$$

Using the boundary conditions $\lambda_{s_n} = \lambda_{g_o} = 0$, it follows that

$$\lambda_{s_o} = \frac{g}{\tau_d} \lambda_{g_n} . \tag{200}$$

Thus, if an approximate value of λ_{g_n} is available from a trajectory similar to the one of interest, a reasonable guess of λ_{s_o} is easily approximated.

D. AUXILIARY COMPUTATIONS

The following paragraphs present the equations employed in a variety of auxiliary computations throughout the program. The computations are termed auxiliary because they do not influence the optimization results or procedures, with the possible exception of the Spiral Capture computations. Rather, the computations are made for printout purposes.

1. Standard Block Print Variables. A standard print block is employed for printing information at various points along a trajectory. Each standard block contains a total of 40 parameters as follows:

TIME — Time since departure, in days.

SEMI-MAJOR AXIS — Semi-major axis of the osculating heliocentric trajectory.

$a = 1/\left(\frac{2}{r} - \frac{v^2}{\mu}\right)$, in AU.

ECCENTRICITY — *Eccentricity of the osculating heliocentric trajectory.*

$e = \sqrt{1 - h^2/\mu a}$, where h is the magnitude of the angular momentum.

INCLINATION — Inclination of the osculating heliocentric trajectory relative to the ecliptic.

$i = \cos^{-1}(\bar{k} \cdot H/h)$, in degrees where H is the angular momentum vector, $H = R \times \mathring{R}$.

NODE — Longitude of ascending node of the osculating heliocentric trajectory plane on the ecliptic, measured eastward from the vernal equinox.

$\Omega = \sin^{-1}\left[\bar{j} \cdot (\bar{k} \times H/h)\right] = \cos^{-1}\left[\bar{i} \cdot (\bar{k} \times H/h)\right]$, in degrees.

ARG POS	Angular position in osculating orbit plane from ascending node measured in direction of motion. $\omega = \cos^{-1}\left[\frac{R \cdot (\bar{k} \times H)}{rh \sin i}\right] = \sin^{-1}\left[\frac{R \cdot [H \times (\bar{k} \times H)]}{rh^2 \sin i}\right]$, in degrees.
RMAG	Magnitude of the instantaneous heliocentric spacecraft position vector. $r = \lvert R \rvert$, in AU.
TRAVEL	Approximate travel angle since launch, in degrees. $\theta_t = \Sigma_i \theta_i$ where $\theta_i = \cos^{-1}\left(\frac{R_i \cdot R_{i-1}}{r_i r_{i-1}}\right)$ and R_i is the spacecraft position vector at the i^{th} computation step.
R1, R2, R3	Cartesian components of current position vector, in AU.
V1, V2, V3	Cartesian components of current velocity vector, in EMOS.
MASS RATIO	Ratio of current mass to initial mass.
THRUST ACC	Ratio of current thrust acceleration to current solar gravity acceleration $(= h_\sigma g \gamma q r^2/\mu\nu)$.
L1, L2, L3	Cartesian components of primer vector, Λ.
L4, L5, L6	Cartesian components of time derivative of primer vector, $\dot{\Lambda}$.
L7	Variable adjoint to the mass ratio, λ_ν.
HAM	Variational Hamiltonian, h_v.
LG	Variable adjoint to the thrust acceleration, λ_g.
LC	Variable adjoint to the jet exhaust speed, λ_c.
LPHI	Variable adjoint to the thrust cone angle, λ_ϕ.

CONE, CLOCK	Two angles, in degrees, defining the angular position of Canopus relative to a spacecraft fixed coordinate system. Employing a built-in unit vector $\bar{s}$ in the direction of Canopus, the two angles are defined

$$\text{CONE} = \cos^{-1} (\bar{s} \cdot \bar{e}_s)$$

$$\text{CLOCK} = \cos^{-1}\left[\frac{(\bar{e}_s \times \bar{e}_t) \cdot (\bar{e}_s \times \bar{s})}{|\bar{e}_s \times \bar{e}_t|\ |\bar{e}_s \times \bar{s}|}\right] = \sin^{-1}\left[\frac{(\bar{e}_s \times \bar{e}_t) \times (\bar{e}_s \times \bar{s})}{|\bar{e}_s \times \bar{e}_t|\ |\bar{e}_s \times \bar{s}|} \cdot \bar{e}_s\right]$$

where $\bar{e}_s$ is a unit vector pointing from the sun to the spacecraft.

HMAG	Magnitude of the angular momentum vector, in AU^2/tau. $h = \lvert R \times \dot{R} \rvert$.
POWER FNCT	The power function γq defined in an earlier section.
SWITCH FNCT	The thrust switch function σ.
PSI, THETA	Thrust angles relative to the instantaneous osculating trajectory plane. PSI is the out-of-plane angle and THETA is the in-plane angle, in degrees.

$$\psi = \sin^{-1} (\bar{e}_t \cdot H/h)$$

$$\theta = \sin^{-1}\left(\bar{e}_t \cdot \frac{H \times R}{hr \cos \psi}\right) = \cos^{-1} (\bar{e}_t \cdot R/r \cos \psi)$$

PHI	Thrust angle relative to the sun-spacecraft line $\phi = \cos^{-1} (\bar{e}_t \cdot R/r)$, in degrees.
LATITUDE	Ecliptic latitude of spacecraft, in degrees $= \sin^{-1} (z/r)$.
LONGITUDE	Ecliptic longitude of spacecraft, in degrees $= \sin^{-1}\left(y/\sqrt{x^2+y^2}\right) = \cos^{-1}\left(x/\sqrt{x^2+y^2}\right)$.

FLT PTH ANGLE — Heliocentric flight path angle, in degrees $= \sin^{-1} (R \cdot \dot{R}/rv)$.

VMAG — Heliocentric speed, in EMOS $v = |\dot{R}|$.

PROP TIME — Total time propulsion system has operated, τ, in days.

The above standard block may be augmented in two ways. When power degradation, as indicated by the input variable TPOWER, is simulated, a single line of information is automatically added to each block, as displayed in the Sample Problems and Results section, Case G, Comet Rendezvous Mission. When the input variable MPRINT is 2 or 3, three extra lines of information are generated per block, as displayed in the Sample Problems and Results section, Case H, Multiple Ballistic Swingby Mission. These two types of additionally printed lines may appear simultaneously.

(a). Power Degradation. The single line of power degradation information contains eight parameters as follows:

S — Degradation time, s, since departure, in days.

LS — Degradation time adjoint variable, λ_s.

DENSITY — Density parameter, d, in AU^{-2}.

DPOWR — $q\partial\gamma/\partial r$, in AU^{-1}.

DPOWD — $q\partial\gamma/\partial d$.

DEGRAD — The degradation factor, q.

CHI — Solar array orientation angle χ, in degrees.

CHI REF — Solar array orientation angle which the arrays would have if oriented for maximum power, in degrees.

(b). Target-Relative Coordinates and Comet Magnitudes. The three extra lines which may appear via using MPRINT contain the following information:

R1 REL R2 REL R3 REL	Cartesian components of current spacecraft position vector, with respect to the next astronomical body to be encountered along the trajectory in a moving coordinate system generated by that body, with the x-axis pointing outward along the body's heliocentric radius vector, the y-axis in the body's orbit plane in the sense of the body's motion, and the z-axis completing the right-handed orthogonal system, in kilometers, with the origin of coordinates at the body.
V1 REL V2 REL V3 REL	Cartesian components of current spacecraft velocity vector, in kilometers/second, in the target-relative coordinate system described directly above (see R1 REL).
RMAG REL	Magnitude of R1 REL, R2 REL, R3 REL, in kilometers.
VMAG REL	Magnitude of V1 REL, V2 REL, V3 REL, in kilometers/second.
S/C NUC MAG	Nuclear magnitude (of comet) of the next astronomical body to be encountered along the trajectory, as seen by the spacecraft. $$M_N = M_o + M_1 \log_{10} \lvert R - R_{targ} \rvert + M_2 \log_{10} \lvert R_{targ} \rvert + .03 \cos^{-1}\left[\frac{R_{targ} \cdot (R_{targ} - R)}{\lvert R_{targ} \rvert \, \lvert R_{targ} - R \rvert}\right] C^o,$$ where M_o, M_1, and M_2 are magnitude constants associated with the target, and C^o is the radians-to-degrees conversion factor. The arc-cosine term is the phase angle.
S/C TOT MAG	Total magnitude of the next astronomical body to be encountered along the trajectory, as seen by the spacecraft. $$M_T = M_3 + M_4 \log_{10} \lvert R - R_{targ} \rvert + M_5 \log_{10} \lvert R_{targ} \rvert$$ where M_3, M_4, and M_5 are magnitude constants associated with the target.

GEO NUC MAG	Same as S/C NUC MAG, except as seen by the Earth.
GEO TOT MAG	Same as S/C TOT MAG, except as seen by the Earth.
ANG(V, R)	Angle which (V1 REL, V2 REL, V3 REL) makes with the positive x-axis in the target-relative coordinate system described under R1 REL, in degrees. ANG(V, R) = $\cos^{-1}$ (V1 REL/VMAG REL)
ANG(V, XY)	Angle which (V1 REL, V2 REL, V3 REL) makes with the xy plane in the target-relative coordinate system described under R1 REL, in degrees. ANG(V, XY) = $\sin^{-1}$ (V3 REL/VMAG REL)
R1 REL ECL R2 REL ECL R3 REL ECL	Same as R1 REL, R2 REL, R3 REL except expressed in the ecliptic coordinate system of date.
V1 REL ECL V2 REL ECL V3 REL ECL	Same as V1 REL, V2 REL, V3 REL except expressed in the ecliptic coordinate system of date.
RMAG ECL	Magnitude of R1 REL ECL, R2 REL ECL, R3 REL ECL, in kilometers.
VMAG ECL	Magnitude of V1 REL ECL, V2 REL ECL, V3 REL ECL, in kilometers/second.

2. Extremum Point Summary Print. For the final trajectory of each case, a table of extremum points of selected functions occurring along the trajectory is evaluated and printed. This table contains the following variables; the number of iterations required to isolate the given point, time from launch, ecliptic longitude, solar distance, communication angle and distance, thrust switch function, the three thrust angles, ψ, θ, and ϕ, the power input to the thrust subsystem, and the array orientation angle χ. Extrema are evaluated for all of these functions except the time from launch, ecliptic longitude, and array orientation angle. In addition, the table includes the initial and final times, all thrust switch

points, and the points at which the power profile changes under Options 4 and 5 of the power function selector. The values of all functions contained in the table are printed each time an extremum or special point of any function is encountered.

Extrema points are evaluated by locating points at which the derivatives of the functions go to zero. The other special points (e.g., thrust switch points) are obtained by defining a function which goes to zero at the special point (e.g., the thrust switch function σ) and isolating these roots. A general set of routines is employed for determining all the extrema and special points. The procedure is to check at each computed point whether any root of interest has occurred within the current (most recent) computation step. If a root is known to exist, an iteration scheme is initiated to isolate the point and store the related information. This is undertaken on all trajectories to define the special points and the extrema of the thrust switch function. The extrema for all other functions are obtained only for information purposes, however, and therefore are evaluated only for the last trajectory of each case.

The ecliptic longitude printed in the table is referenced to the longitude at launch; consequently, the value printed at the initial time is zero. Thereafter, the longitude is accumulated in increments so that the value will exceed 360 degrees if the spacecraft traverses more than one revolution of the sun. The angle is printed in degrees.

The solar distance is simply the magnitude of the spacecraft's heliocentric position vector and is printed in AU. Extrema of the function are obtained by isolating those points where $\dot{r} = R \cdot \dot{R}/r$ is zero.

The communication distance is defined to be the distance from the Earth to the spacecraft and is evaluated in AU as follows:

$$r_c = |R - P_e| , \tag{201}$$

where P_e is the heliocentric position of the Earth. The extrema in r_c are evaluated by locating the points when

$$(R - P_e) \cdot (\dot{R} - \dot{P}_e) = 0 \; . \tag{202}$$

The communication angle is the angle in degrees subtended at the Earth between the Earth-spacecraft and Earth-sun lines. It is evaluated as follows:

$$\alpha_c = \cos^{-1}\left[\frac{P_e \cdot (P_e - R)}{|P_e|\;|P_e - R|}\right], \tag{203a}$$

except at the initial time when $R = P_e$; then,

$$\alpha_c = \cos^{-1}\left[\frac{P_e \cdot (\dot{P}_e - \dot{R})}{|P_e|\;|\dot{P}_e - \dot{R}|}\right]. \tag{203b}$$

Extrema of this communication angle correspond to the roots of the equation,

$$\frac{\left[(R - P_e) \times (\dot{R} - \dot{P}_e)\right] \times (R - P_e)}{|P_e|\;|R - P_e|^3} \cdot P_e + \frac{(P_e \times \dot{P}_e) \times P_e}{|R - P_e|\;|P_e|^3} \cdot (R - P_e) = 0. \tag{204}$$

The above equations for communication distance and angle assume that the input parameter NDIST is set to its default value of 3, which corresponds to Earth. Any other celestial body may be chosen as the reference for the calculations, through proper choice of NDIST, in which case the vectors P_e and $\dot{P}_e$ then represent the position and velocity vectors,. respectively, of the corresponding reference body.

The thrust switch function is evaluated as defined earlier. Extrema of the thrust switch function correspond to the roots of the equation*,

$$\dot{\sigma} = \dot{\Lambda} \cdot \bar{e}_t + \Lambda \cdot \dot{\bar{e}}_t - h_\sigma \frac{g\gamma}{\nu c}\,\sigma - \frac{\nu\gamma'}{g\gamma^2 r}\,(R \cdot \dot{R})\,\lambda_\tau = 0 \; , \tag{205}$$

*In the absence of power degradation; $\dot{q} \equiv 0$.

with

$$\dot{\bar{e}}_t = \frac{1}{|\Lambda|^3} \left[(\Lambda \times \dot{\Lambda}) \times \Lambda \right], \tag{206}$$

if thrust direction is not constrained, and

$$\dot{\bar{e}}_t = \dot{\bar{e}}_r \cos \phi + (\dot{\bar{m}} \times \bar{e}_r + \bar{m} \times \dot{\bar{e}}_r) \sin \phi , \tag{207}$$

if thrust cone angle ϕ is constrained where

$$\begin{aligned}
\bar{e}_r &= R/r, \\
\dot{\bar{e}}_r &= \frac{1}{r^3} \left[(R \times \dot{R}) \times R \right], \\
\bar{e}_\lambda &= \Lambda/\lambda, \\
\dot{\bar{e}}_\lambda &= \frac{1}{\lambda^3} \left[(\Lambda \times \dot{\Lambda}) \times \Lambda \right], \\
\bar{m} &= \frac{R \times \Lambda}{|R \times \Lambda|} , \\
\dot{\bar{m}} &= \frac{\bar{m}}{|\bar{e}_r \times \bar{e}_\lambda|} \times \left[(\dot{\bar{e}}_r \times \bar{e}_\lambda + \bar{e}_r \times \dot{\bar{e}}_\lambda) \times \bar{m} \right].
\end{aligned} \tag{208}$$

The extrema of the thrust angles ψ, θ and ϕ are defined by isolating the points at which their time derivatives vanish. For the case of unconstrained thrust angles, these derivatives are defined:

$$\begin{aligned}
\dot{\psi} &= \frac{1}{\cos \psi} \left(\dot{\bar{e}}_t \cdot \bar{e}_h + \bar{e}_t \cdot \dot{\bar{e}}_h \right), \\
\dot{\phi} &= - \frac{1}{\sin \phi} \left(\dot{\bar{e}}_t \cdot \bar{e}_r + \bar{e}_t \cdot \dot{\bar{e}}_r \right) , \\
\dot{\theta} &= \frac{1}{\sin \theta \cos \psi} \left(\sin \phi \, \dot{\phi} - \cos \theta \sin \psi \, \dot{\psi} \right), \\
&= \frac{1}{\cos \theta \cos \psi} \left(\dot{\bar{e}}_t \cdot \bar{e}_v + \bar{e}_t \cdot \dot{\bar{e}}_v + \sin \theta \sin \psi \, \dot{\psi} \right) ,
\end{aligned} \tag{209}$$

where $\dot{\bar{e}}_t$ is as defined above for the unconstrained thrust angle case, and

$$\begin{aligned}
\bar{e}_h &= (R \times \mathring{R})/|R \times \dot{R}| = H/h, \\
\dot{\bar{e}}_h &= \frac{1}{h^3}\left[(H \times \mathring{H}) \times H\right], \\
\mathring{H} &= h_\sigma \frac{g\gamma q}{\nu} (R \times \bar{e}_t), \\
\bar{e}_v &= \bar{e}_h \times \bar{e}_r, \\
\dot{\bar{e}}_v &= -\frac{h}{r^2} \dot{\bar{e}}_r .
\end{aligned} \tag{210}$$

The two expressions for $\dot{\theta}$ are employed to avoid singularities when either $\sin\theta$ or $\cos\theta$ vanish.

For the case of constrained thrust cone angle, no extrema of the cone angle ϕ is sought since the angle is a constant. The derivatives of the other two angles are as defined above using the expression for $\dot{\bar{e}}_t$ appropriate to the case of constrained cone angle and setting $\mathring{\phi} = 0$.

The instantaneous power input to the thrust subsystem, in kilowatts, is also listed. Extrema of this function are isolated by locating the roots of the function $d(\gamma q)/dt$.

3. Swingby Continuation Analysis. Auxiliary computations are optionally provided, invoked by the NAMELIST input vector MOPT4, whereby ballistic swingbys past the primary target may be simulated.

In one mode of program operation, invoked by MOPT4(1) > 0, single swingbys past the primary target may be simulated to up to ten post-swingby targets per case.

In another mode of program operation, invoked by MOPT4(1) < 0, multiple swingbys along a single trajectory may be simulated, first swinging past the primary target and then subsequently swinging past more targets downstream along the trajectory. One multiple swingby trajectory may be simulated per case.

In either mode of operation, the following basic assumptions are made. The swingby continuation computations are independent of the trajectory leg leading up to the swingby target, which may consist of an optimized electric propulsion trajectory segment (if the swingby planet is the primary target), except that the arrival V_∞ and arrival time at the swingby planet are used in the determination of the swingby passage conditions. Each swingby maneuver is calculated under the assumption of the patched-conic approximation, and the swingby planet's sphere-of-influence is assumed to have zero radius as seen from interplanetary space and infinite radius as seen from the planetary vantage point. The passage time in the swingby planet's sphere-of-influence is neglected (taken to be zero in the heliocentric frame).

Each swingby maneuver may be either unpowered or powered, and these two cases are discussed in the following sections. Since the unpowered swingby solutions are embedded in the wider class of powered-swingby solutions, tending to appear in pairs which are separated by a region of braking powered swingbys, the more general case of powered swingbys is discussed first.

(a). Powered Swingbys. This type of swingby maneuver is restricted to occur at the mutual perifoci of the approach and departure hyperbolic arcs; the powered phase is impulsive and the thrust is colinear (pro or con) to the velocity at closest approach. Whether the swingby is powered or unpowered, the trajectory segment leading up to the swingby planet has been pre-determined, this being the method by which the program has been designed to obtain swingby solutions. Therefore the swingby time and the arrival hyperbolic excess velocity

$V_{\infty A}$ are known. In the following analysis, subscript A pertains to arrival at the swingby planet and subscript D pertains to departure.

A basic assumption of the powered swingby problem posed here is that the flight time from the swingby planet to the next target is specified. This being so, the program is able to converge, by iteration, on some ballistic trajectory from the swingby planet to the next target having the specified transfer time, implying that the departure hyperbolic excess velocity $V_{\infty D}$ at the swingby planet is thereby determined. Therefore, the heliocentric trajectory before and after the swingby planet is determined, and it then remains to perform the required computations pertaining to the hyperbolic arcs within the swingby planet's sphere of influence.

The closest approach distance is found by iteration as follows. Let

$$\alpha_A = 1 + \frac{r_p v_{\infty A}^2}{\mu} , \tag{211}$$

and

$$\alpha_D = 1 + \frac{r_p v_{\infty D}^2}{\mu} , \tag{212}$$

where $v_{\infty A} = |V_{\infty A}|$, $v_{\infty D} = |V_{\infty D}|$, r_p is the (unknown) passage distance, and μ is the swingby planet's gravitational parameter. Then the approach and departure hyperbolic bend angles are given by

$$\begin{aligned} \frac{\delta_A}{2} &= \operatorname{cosec}^{-1} \alpha_A = \sin^{-1} (1/\alpha_A), \\ \frac{\delta_D}{2} &= \operatorname{cosec}^{-1} \alpha_D = \sin^{-1} (1/\alpha_D) , \end{aligned} \tag{213}$$

and these must sum up to the total bend angle, which is specified in terms of $V_{\infty A}$ and $V_{\infty D}$:

$$\delta_T = \frac{\delta_A}{2} + \frac{\delta_D}{2} = \cos^{-1}\left[\frac{V_{\infty A} \cdot V_{\infty D}}{v_{\infty A}\, v_{\infty D}}\right] . \tag{214}$$

Therefore, using r_p as the independent variable, the zero of the quantity

$$F = \sin^{-1}(1/\alpha_A) + \sin^{-1}(1/\alpha_D) - \cos^{-1}\left[\frac{V_{\infty A} \cdot V_{\infty D}}{v_{\infty A}\, v_{\infty D}}\right] \tag{215}$$

is obtained by Newton's iteration, using the derivative,

$$\frac{\partial F}{\partial r_p} = \left(\frac{-1}{\mu}\right)\left[\frac{v_{\infty A}^2/\alpha_A}{\sqrt{\alpha_A^2 - 1}} + \frac{v_{\infty D}^2/\alpha_D}{\sqrt{\alpha_D^2 - 1}}\right]. \tag{216}$$

When the iteration is converged, the passage distance r_p is in hand, and the impulsive velocity increment is computed,

$$\Delta v = \sqrt{\frac{2\mu}{r_p} + v_{\infty D}^2} - \sqrt{\frac{2\mu}{r_p} + v_{\infty A}^2} , \tag{217}$$

where the square-root-quantities are the hyperbolic speeds at closest approach. The remaining parameters defining the planetocentric transfer are computed as follows. The inclination of the swingby orbit plane to the planet's equator is given by

$$i = \cos^{-1}(\bar{h} \cdot \bar{n}_p) , \tag{218}$$

where $\bar{h}$ is the unit vector along the angular momentum of the hyperbolic passage trajectory and $\bar{n}_p$ is a unit vector pointing toward the swingby planet's north pole. The ascending node angle of the swingby orbit plane is computed as,

$$\Omega = \tan^{-1}(-h_x/h_y), \tag{219}$$

and is placed in the proper quadrant by using the system library routine DATAN2. The argument of perifocus is given by,

$$\omega = \cos^{-1}(\bar{r}_p \cdot \bar{r}_n), \tag{220}$$

where $\bar{r}_p$ is the unit vector pointing toward the closest approach point and $\bar{r}_n$ is the unit vector lying along the line of nodes and pointing toward the ascending node. This is adjusted for the proper quadrant by the test,

$$\text{If } h_z (\bar{r}_n \times \bar{r}_p)_z < 0, \qquad \omega \rightarrow 2\pi - \omega.$$

In the right-handed planetary reference frame, the z-axis is toward the planet's north and the x-axis points toward the ascending node of the planet's equator on the ecliptic.

(b) Unpowered Swingbys. This type of swingby maneuver is considered to be a powered swingby having $\Delta v = 0$. The program adjusts the post-swingby heliocentric trajectory segment, by iteration, until the swingby departure V_∞ magnitude equals the given arrival V_∞ magnitude. The primary independent variable in this iteration is the post-swingby transfer time to the specified target, which was held constant in the powered swingby case. Thus $v_{\infty D} = v_{\infty A} = v_\infty$, and the swingby passage distance is obtained from the formula,

$$r_p = \frac{\mu}{v_\infty^2} \left(\frac{2v_\infty}{|V_{\infty A} - V_{\infty D}|} - 1 \right). \tag{221}$$

The other orbital parameters are obtained from the same relations given above in the section, Powered Swingbys.

The program can generate multiple-revolution ballistic arcs, and a particular solution obtained by the program may not be unique, even for the same transfer time. All solutions are reachable, however, by means of inputting an appropriate initial velocity guess for the trajectory segment in question.

4. Spiral Capture. The program provides the option of computing approximate performance requirements of an electric propulsion spiral capture

maneuver at the primary target planet. The approximation is based on asymptotic matching techniques developed by Fimple and Edelbaum (Reference [9]) and by Breakwell and Rauch (Reference [10]). The technique assumes that a heliocentric trajectory to a conceptually massless point with position and velocity of the primary target planet is available. The approximation then yields the additional propellant and propulsion time that would be required above that of the heliocentric trajectory to insert the spacecraft into an orbit of periapse r_p and apoapse r_a using the electric propulsion spiral maneuver. It should be noted that the additional propellant and time computed in this approximation does not represent the propellant and time spent performing the spiral with very high accuracy because the heliocentric trajectory included a trajectory segment which was within the geometric boundaries of the sphere of influence of the planet. The additional propellant and time computed is more appropriately considered a correction to the heliocentric trajectory which, when added to the requirements of the heliocentric trajectory, yields a good estimate of the total performance requirement, including those of the spiral.

Defining the semi-major axis of the capture ellipse,

$$a_c = (r_a + r_p)/2, \tag{222}$$

and the thrust acceleration at the end of the heliocentric trajectory

$$a_n = g\gamma q/\nu_n, \tag{223}$$

then an incremental velocity associated with the spiral maneuver is calculated,

$$\Delta v = \sqrt{\frac{\mu_t}{a_c}}\left[1 - 1.84\left(\frac{a_n a_c^2}{\mu_t}\right)^{\frac{1}{4}}\right], \tag{224}$$

which leads to the additional propellant

$$\Delta m_p = m_o \nu_n (1 - e^{-\Delta v/c}), \tag{225}$$

and the additional time

$$\Delta t = c(1 - e^{-\Delta v/c})/a_n \, . \qquad (226)$$

This option is invoked with the input parameter MTMASS.

E. SPECIAL PROGRAM FEATURES

The following paragraphs describe several special features available in HILTOP which are provided to alleviate certain numerical difficulties and to increase the program's generality and flexibility.

1. Perturbation Step Size Selector. The program generates a partial derivative matrix of the dependent variables with respect to the independent variables by integrating trajectories neighboring the current nominal trajectory. The perturbation step size of each independent variable, which is used to vary that lone variable in order to generate its associated neighboring trajectory, may be input to the program. Each neighboring trajectory is used to generate one column of the partial derivative matrix, each element of which is constructed by forming the simple ratio of the difference between the neighboring and nominal dependent variable values to the perturbation step size. Each element of the matrix thus constructed represents the secant-slope-approximation to the actual dependent variable slope, and this approximation comes closest to the true value for some unique perturbation step size value for each independent variable. The approximation becomes poor for large step sizes because the secant-slope deviates farther from the true slope, and becomes poor for very small step sizes because the numerical accuracy of the computer and also of the trajectory generation algorithm with its numerous iterations introduces computational noise.

A program option controlled by the input variable KPART is available which attempts to determine the optimum perturbation step size for each independent variable. The program accomplishes this by taking a linear walk in the base-10 logarithm of each independent variable step size starting from the input or default value and not exceeding KPART steps. The program first steps in each direction (smaller and larger step size) to determine the proper direction of the walk, and each step consists of varying the step size one-half order-of-magnitude. For each linear walk (for each independent variable), that one column

of the partial derivative matrix associated with the independent variable is computed for each step of the walk, and each element of that column is compared between the n^{th} step and the $(n + 1)^{th}$ step of the walk. The element which has the largest normalized error in comparing the n^{th} and the $(n + 1)^{th}$ steps is selected as the criterion function, and this maximum-error-element is allowed to vary as the walk progresses. The walk continues until the criterion function is minimized, at which point the optimum perturbation step size is considered to be determined to within one-half order-of-magnitude. The process is repeated for each independent variable perturbation step size, to arrive at an optimum set of step sizes, which are then input to the program's iterator in place of the original values. A summary of the step size optimization is printed.

2. Avoiding Corners in the Propulsion-Time Function. The program monitors the thrust switching function along each trajectory to determine when to optimally switch the thrust on or off (at the roots of the switch function). At times the program's iterator moves the trajectory into a region where two successive switch function roots approach each other and become very close together, which physically represents very rapid thrust-switching, and which mathematically represents a corner in the propulsion-time function. This means that the iterator is attempting to either add or eliminate a coast phase or a thrust phase to the trajectory. The iterator has severe difficulty when switch function roots become very close together, simply because this represents a crease in the otherwise-smooth dependent variable functions of the boundary value problem, and the iterator is not designed to handle such situations. To avoid this difficulty, a program option controlled by the input variables GAP and NHUNG is available which monitors the closeness of the switch function roots. When the program detects that the iterator is having difficulty with a propulsion-time corner, the program halts the iterator, returns logic control to the MAIN program, and introduces two cases (in addition to the user's input cases). The first additional case avoids the propulsion-time corner by forcing the spacecraft to thrust continuously

throughout the mission. After the iterator attains convergence with forced-thrusting, the program attempts to converge on the original case using the forced-thrusting trajectory as the initial guess. The program generates the forced-thrusting trajectory by setting $\lambda_\tau = 10\,\lambda_\nu(t_o)$.

3. Lagrange Multiplier Scaling. The Lagrange multipliers, or adjoint variables Λ and $\mathring{\Lambda}$, at the start of each trajectory segment may be scaled such that the initial mass-ratio Lagrange multiplier has unit magnitude. The program will do this automatically if the input variable NORMAL is set equal to one.

4. Generation of an ASTEA Tape. The HILTOP program is capable of generating a trajectory tape or sequence of punched cards suitable for input to the ASTEA (Arbitrary Space Trajectory Error Analysis) computer program[11]. This is accomplished by means of the NAMELIST input variables MPUNCH and NTAPE. The contents of the HILTOP output tape or punched cards are described in the section, Program Output.

5. Scratch Pack Output. The HILTOP program was developed for use at the computing facility at the NASA Goddard Space Flight Center. That facility supports conversational remote input terminals, and special provisions have been made in the program for effective use with the remote terminals. Specifically, fortran WRITE statements are included throughout the program to direct selected program output to unit 11 and unit 12 output devices. Job control cards are used to define these units to be special disk packs from which the data can be retrieved and printed at the remote terminals. If this feature is not wanted or is incompatible at the installation, IBM JCL DD DUMMY cards for each unit may be included in the job control cards. The run summary is written on unit 12, and the iterator independent and dependent parameter values are written on unit 11. The independent variables are written in a format compatible with NAMELIST input and therefore may be used directly in a continuation run.

6. Normal Run Termination. The computing facility at NASA GSFC requires as input an estimate of the machine time necessary to execute the run. The operating system will not permit this time to be exceeded, and it automatically terminates the run if the input time estimate is reached. To avoid losing valuable information should this occur, the time remaining for the run is continually monitored during execution (using the GSFC library routine REMTIM). If the remaining time becomes less than an input number of seconds, control in the program is transferred to MAIN which causes the most recent trajectory to be integrated and all requested information printed for that trajectory. The run then terminates normally. REMTIM is called only from subroutine TIKTOK, and may be dummied by setting its two arguments to 100.

7. Ballistic Trajectory Option. HILTOP specifically contains the ability to generate one- or two-impulse ballistic interplanetary transfer trajectories, i.e., trajectories that do not use an electric propulsion system. The impulse at launch is provided by the indicated launch vehicle, while the impulse at the primary target, if required, is accomplished with a retro stage defined by input characteristics. Two options are available for generating ballistic trajectories.

The first option is simply to use the program in the same manner as for electric propulsion trajectories but force the thrust switch function to always be negative such that the electric propulsion engine never turns on. This is most easily accomplished by setting the input parameter IBAL equal to 1. This simply causes the program to set a number of parameters internally to assure that a ballistic trajectory is generated. The program uses the coast phase solution to generate the trajectories and the iterator is employed to converge on the desired end conditions.

The second option is more straightforward and automatic. Setting the input parameter MOPT equal to 1 causes the program to generate a ballistic

flyby transfer from the launch planet to the specified primary target; setting MOPT equal to 2 results in the generation of a ballistic rendezvous trajectory to the specified primary target. In this option the ballistic trajectory is computed before entering the logic in which electric propulsion trajectories are normally evaluated. Therefore, this procedure may be used to obtain the impulsive solution as a first guess to the electric propulsion trajectory, since this option automatically generates values for the initial adjoint variables Λ_o and $\dot{\Lambda}_o$ and also for $v_{\infty o}$.

The latter option requires fewer inputs and less detail to obtain the ballistic trajectory, but is restricted to fixed launch date, fixed arrival date single-target cases. The former option may be used for multiple-target missions and permits one to optimize the launch and/or arrival dates because the appropriate transversality conditions are valid for ballistic as well as electric propulsion trajectories. It is sometimes very convenient to use the two options sequentially, using the second option in the first input case to get Λ_o, $\dot{\Lambda}_o$ and $v_{\infty o}$, and then using the first option in the second input case to get the full computational and printout advantages of the program.

8. Rotation of Primer Vector with Launch Date. The mission analyst is frequently faced with a problem of possessing a solution for one launch date and desiring a solution for a different launch date. Theoretically, such a problem may be solved by treating launch date as both an independent parameter and a dependent parameter. However, unless the launch date difference is relatively small, this approach to the solution often leads to numerical difficulties due to high sensitivities of the trajectory to arbitrary changes in the components of the initial primer vector and its time derivative.

Generally, the initial primer vector and its derivative will maintain similar relationships to the initial position vector as launch date is varied. Consequently, a simple rotation of the vectors through an angle equal to the

displacement of two initial position vectors will often yield acceptable first guesses of the multipliers from which convergence can be achieved. An option is provided, using the input parameter IROT, which automatically accomplishes the rotation of Λ_o and $\dot{\Lambda}_o$. In using this option, a case must first be executed to initialize the position vector of the original case. This initialization may be accomplished by running a single trajectory or a regular iteration. In either case, the initial position of the last trajectory generated is used as the reference position. On the next case, the parameter IROT should be set to a non-zero value and the initial position vector is evaluated using the (supposedly) new launch date. The angle between this new position vector and the reference position is evaluated, and Λ_o and $\dot{\Lambda}_o$ from the preceding case are rotated through this angle about the ecliptic North Pole. The rotated vectors are then used as initial guesses for the second case.

9. Limitation of Power to Power Processors. An input variable, GAMMAX, provides an option of simulating the limitation of a maximum power that can be processed by the power conditioners. For example, the propulsion system may conceivably be designed for a maximum power equal to that developed by the arrays at 1 AU. If a trajectory passed through a perihelion distance less than 1 AU, the power developed by the arrays might exceed the design point. Using this option, the program would simulate the constraint by assuming the arrays are tilted to the sun line by an amount necessary to reduce the power factor γ to a value equal to GAMMAX. The solar distance below which the arrays must be tilted is evaluated internally and depends on the coefficients of the solar power law. This distance is evaluated once for each case, and the array tilting is triggered on crossing this solar distance. The option may be used with the power degradation option, but the tilt angle does not take $q < 1$ into account. To invoke this option, it is necessary to set MODE = 5.

10. Housekeeping Power. This program option applies to solar electric propulsion and is currently not combined with the power degradation

option. The program therefore does not allow the use of both options simultaneously. The program input quantity controlling the housekeeping power simulation is DPOW, which is the ratio of housekeeping power to reference power and is given the symbol Δp:

$$\Delta p = p_h/p_{ref} \,. \tag{227}$$

This spacecraft model assumes that the power required by the operating components at each instant of time exactly match the power developed by the solar arrays:

$$p_a = p + p_h \,, \tag{228}$$

where p_a is the power developed by the arrays, p is the instantaneous power delivered to the power conditioners, and p_h is the housekeeping power, which is constant with time. Currently, all trajectories generated by the program using the housekeeping power simulation must satisfy the condition that $p_a > p_h$, so that p remains positive; in other words, engine shutdown when $p \to 0$ is not coded into the program.

11. Imposed Coast Phases. It is occasionally desirable to impose coast phases over specified time intervals of a trajectory. The option is provided through the two input arrays TOFF and TCOAST to impose up to 20 coast phases throughout a trajectory. To invoke this option, the elements of TOFF must contain an ascending sequence of times, in days from launch, at which the engines are shutdown. Corresponding elements of TCOAST define the duration, in days, of the associated coast phases. To work properly, one should assure that

$$\mathrm{TCOAST(I)} < \mathrm{TOFF(I+1)} - \mathrm{TOFF(I)}.$$

An imposed coast phase may partially or completely overlap an optimum coast phase and vice-versa.

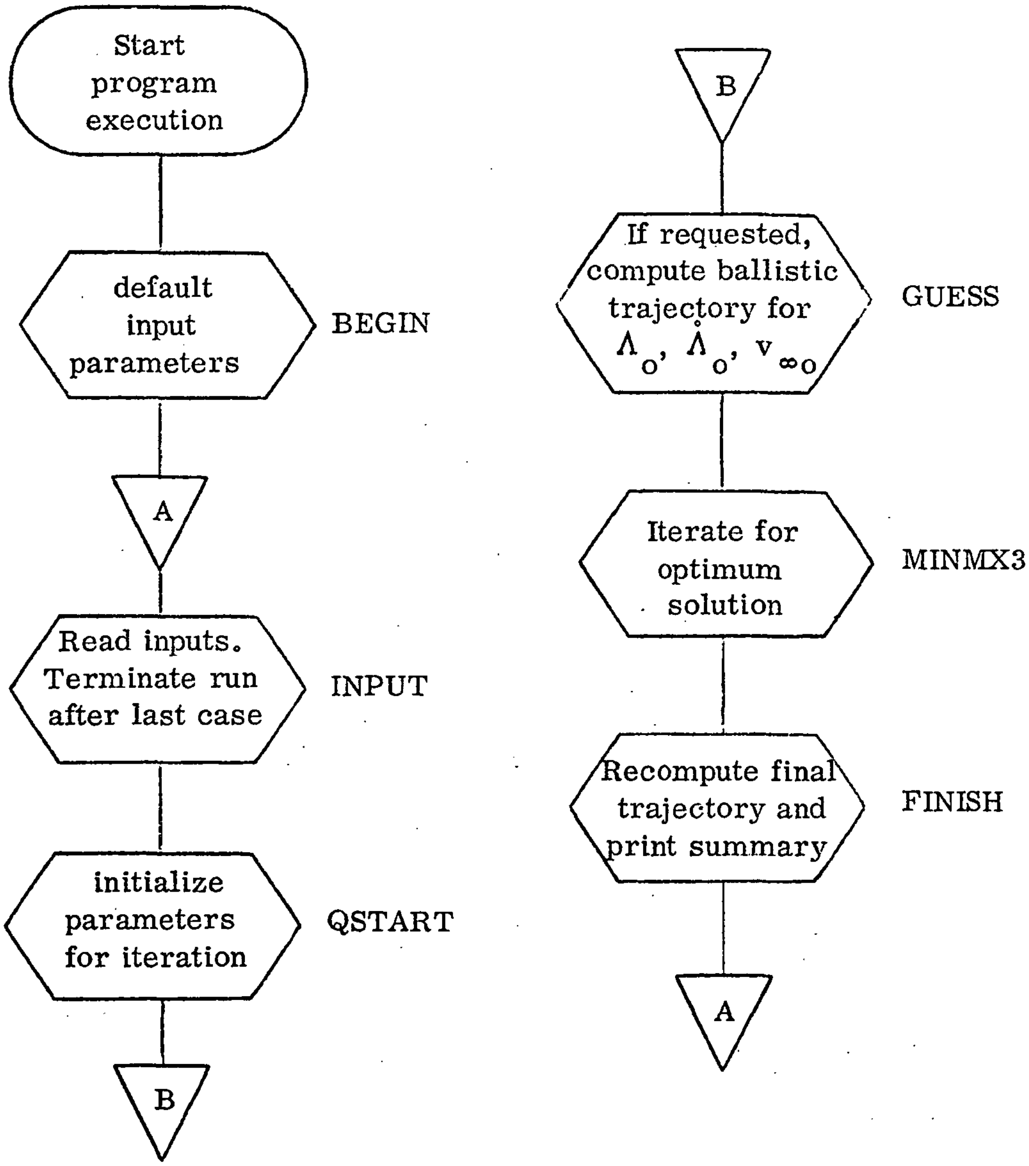
III. PROGRAM DESCRIPTION

This section provides a users' manual of the HILTOP program and provides an introduction to the basic logic flow of the program. A brief description of the function of each routine is provided in a subroutine glossary, along with a subroutine calling sequence table. Subroutine and labelled common cross reference tables are presented, followed by tables of each labelled common variable cross referenced to every subroutine referencing the variable. A complete list and description of the input parameters are given and are followed by a description of the computer program output.

The job control language required to execute an object program module residing on a user disc pack at the GSFC IBM 360, Model 91 computer facility is presented. Additionally, the basic machine requirements for program execution on the GSFC 360/91 system are presented.

A. PROGRAM STRUCTURE

1. <u>MAIN Program.</u> The subprogram MAIN represents the first execution entry-point and the primary driver of the HILTOP program. MAIN calls the routines which read the program inputs and perform initialization computations for each case, transfers control to the iterator, and calls the summary print routines after the iteration phase is completed. A logical flow chart of MAIN is presented below.



2. Subroutine Glossary.

AEINWT	Assigns target body orbit elements for selected comets and asteroids.
ALBEDO	Computes photometric magnitude of a given astronomical body as seen by both the spacecraft and an observer on Earth.
ANSTEP	Takes analytic coast-phase step in state and adjoint variables.
BEGIN	Assigns default values prior to reading input.
BOOSTR	Initializes launch vehicles coefficients. Entry point in OMASS.
CARKEP	Converts from Cartesian position and velocity vectors to Keplerian orbital elements.
CDERIV	Computes functions monitored by subroutine CHECK.
CHECK	Monitors trajectory for engine switch points, target times and other extremum-table entries.
CHECKI	Initializes CHECK for each trajectory. Entry point in CHECK.
CHKINT	Initializes CHECK for each trajectory segment. Entry point in CHECK.
CONVER	Converts vector from ecliptic to equatorial coordinate system.
CONVRT	Converts derivatives between time and generalized universal anomaly.
CORNER	Initializes quantities for additional cases which avoid propulsion-time corners.
DATE 1	Computes Julian Date from calendar date.
DECLIN	Computes launch asymptote declination.
DERIV	Evaluates derivatives of state and adjoint variables for numerical integration.

EFM	Computes target position, velocity and acceleration using stored or input osculating elements.
EFMPRT	Prints target and spacecraft position and velocity at target-intercept times.
ETA	Computes engine efficiency and first derivative with respect to jet exhaust speed.
ETAINT	Initializes constant coefficients for engine efficiency. Entry point in ETA.
EXTAB	Prints extremum table of selected functions.
FINISH	Recomputes final trajectory for full program printout, case summary, optional punched cards and trajectory tape generation.
FUNCT	Computes auxiliary functions required at each computation step.
GET I	Computes launch parking orbit inclination.
GET Q	Computes iterator dependent variables.
GET RV	Computes optimum final position and velocity for extra-ecliptic missions.
GUESS	Main control subroutine for iteration to find ballistic two-body trajectory and associated adjoint variables between specified end conditions in given flight time.
GUNTHR	Computes minimum impulsive speed between circular orbit and hyperbolic orbit and derivatives with respect to v_∞ and i_∞.
IMPRNT	Prints initial and final positions and velocities each iteration in GUESS.
IMPULS	Trajectory generator used by GUESS.
INCOND	Transforms position and velocity from polar to Cartesian coordinates.
INPUT	Reads and writes program inputs (NAMELIST) for each case.
INTERP	Interpolates for roots of functions monitored by CHECK.

C-2

LOAD	Computes quantities for extremum table.
MAIN	Program entry and master control.
MINMX3	Generalized iteration and parameter optimization routine.
MORE	Controls ballistic swingby continuation analysis and computes ballistic trajectory extension beyond primary target.
OMASS	Computes for a specified launch vehicle, the initial spacecraft mass and derivatives with respect to v_∞ and i.
PARINC	Adjusts perturbation step sizes to maximize accuracy of partial derivative matrix.
PDATE	Computes year, month, day, hour from Julian date.
PMPINT	Establishes dimensions for partial derivative matrix print routine.
PMPRNT	Partial derivative matrix print routine. Entry point in PMPINT.
PRINT	Prints iterator independent and dependent variables on scratch packs (units 11 and 12).
PRINTR	Iterator summary print routine.
PRIOR	Saves integrated variables and restores their derivatives at each computation step.
PUNCH	Punched card and magnetic tape output routine.
QPRINT	Case setup and summary print routine.
QSTART	Performs initialization computations for each case.
RADAR	Evaluates communication distance and angle.
READER	Reads special A-format input cards containing independent parameters. Entry point in PUNCH.
RETINJ	Computes retro engine or electric propulsion spiral performance requirements at primary target.
RIDGE	Monitors propulsion-time corner proximity. Entry point in CORNER.

RKSTEP	Takes thrust-phase step (fourth-order Runge-Kutta integration).
SCOMP	Series computation for f and g series solution of trajectory during coast phases.
SETUP	Computes iterator logical variables, primarily for use in GET Q.
SIMEQ	Solves a system of simultaneous linear equations. Entry point in SMQINT.
SMQINT	Initializes for SIMEQ.
SOLAR	Computes spacecraft power ratio γq and related parameters.
SOLINT	Initializes for SOLAR. Computes solar power law critical radii by iteration when coefficients are input. Entry point in SOLAR.
SPRINT	Point by point trajectory print routine.
STEP	Performs a computation step along a trajectory.
STORE	Reorders and removes multiple entries in extremum table.
STOREI	Initializes for STORE. Entry point in STORE.
SUMMRY	Stores specific quantities and prints run summary.
SWING	Computes ballistic swingby continuation trajectory to specified post-swingby target.
SWPRNT	Dummy print routine passed to MINMX3 through its argument list. Entry point in SWTRAJ.
SWSTO	Stores output data at switch points. Monitors Hamiltonian accuracy.
SWTRAJ	Trajectory generator used by SWING.
TAP	Trajectory integration supervisor. Computes one trajectory segment.
TAPSET	Initializes parameters which force TAP to generate a ballistic trajectory segment.
TFORM	Vector transformation routine. Entry point in VSCAL.

THANG	Computes thrust unit vector in fixed cone angle case. Entry point in THANGD.
THANGD	Computes time derivative of thrust unit vector in fixed cone angle case.
TIKTOK	Monitors remaining execution time on computer, by calling REMTIM. Provides normal run termination.
TRAJ	Basic mapping routine for the MINMX3 iterator. Supervises trajectory-segment computation and initializes for GET Q.
TRAJI	Initialization for the beginning of each trajectory.
TRAVEL	Computes incremental travel angle.
TRJINT	Initialization for TRAJ. Entry point in TRAJ.
TWINKL	Computes unit vector in direction of Canopus.
UNITD	Computes time derivative of a unit vector along an arbitrary vector, given the arbitrary vector and its time derivative. Entry point in VSCAL.
VADD	Vector addition routine. Entry point in VSCAL.
VCROSS	Vector cross product routine. Entry point in VSCAL.
VDOT	Vector dot product routine. Entry point in VMAG.
VMAG	Vector magnitude routine.
VPRINT	Print routine for optimum COV Earth departure (e.g., NERVA).
VSCAL	Computes product of a scalar and a vector.
VSUB	Vector subtraction routine. Entry point in VSCAL.

Detailed descriptions of all subroutines are presented at the back of this document.

3. Subroutine Calling Sequence. The table on the following two pages displays the hierarchy of calls to the various subroutines in the program. The order of subroutine names shown is approximately the order in which the calls occur in the listings, but not necessarily the order they occur in the logic flow. Multiple calls to any given routine from another routine are noted only once in the table. The table on the third page following presents the same information in a different format. Each subroutine is listed alphabetically and is followed by a list of all sub-programs that reference the subroutine.

As noted in the sequence table following, the program contains a number of secondary entry points within selected sub-programs. A complete list of these entry points follows.

Entry Point	Sub-program
CHECKI	CHECK
CHKINT	CHECK
RIDGE	CORNER
ETAINT	ETA
BOOSTR	OMASS
PMPRNT	PMPINT
READER	PUNCH
SIMEQ	SMQINT
SOLINT	SOLAR
STOREI	STORE
SWPRNT	SWTRAJ
THANG	THANGD
TRJINT	TRAJ
VDOT	VMAG
VCROSS	VSCAL
VADD	VSCAL
VSUB	VSCAL
UNITD	VSCAL
TFORM	VSCAL

```
MAIN  ┌TIKTOK ┬ REMTIM
      │       ├ FINISH ───── (SEE BOTTOM OF PAGE)
      │       └ SUMMRY
      ├BEGIN
      ├QSTART ┬ DATE1
      │       ├ AEINWT ───── DATE1
      │       ├ SOLINT*
      │       ├ EFM
      │       ├ QPRINT ───── (SEE CALL BY FINISH)
      │       ├ SETUP
      │       ├ BOOSTR*
      │       ├ ETAINT*
      │       ├ TWINKL
      │       └ TRJINT* ──┬ETA
      │                   ├OMASS  ┬DECLIN
      │                   ├RETINJ ├GUNTHR
      │                   └EFM    └GET I ── GUNTHR
      ├INPUT ──── TIKTOK ──── (SEE TOP OF PAGE)
      ├READER*
      ├CORNER
      ├GUESS ──┬ MINMX3 ───── (SEE CALL BY MAIN)
      │        ├ IMPULS ────┬SCOMP
      │        ├ SMQINT     └ANSTEP┬PRIOR
      │        └ SIMEQ*            └SCOMP
      ├MINMX3 ┬ SMQINT
      │       ├ PMPINT
      │       ├ TIKTOK ───── (SEE TOP OF PAGE)
      │      {├ TRAJ ─────── (SEE NEXT PAGE)
      │   PD5{├ SWTRAJ ───── (SEE CALL BY SWING BELOW)
      │      {├ IMPULS ───── (SEE CALL BY GUESS ABOVE)
      │      {├ PRINTR
      │CCHECK{├ SWPRNT
      │      {├ IMPRNT
      │       ├ PARINC ───── TRAJ ──── (SEE NEXT PAGE)
      │       ├ PMPRNT*
      │       └ SIMEQ*
      └FINISH ┬ TRAJ ─────── (SEE NEXT PAGE)
              ├ PRINTR
              ├ PRINT
              ├ EXTAB
              ├ QPRINT ────┬EFMPRT-PDATE
              ├ SUMMRY     ├BOOSTR*
              ├ CORNER     ├PDATE
              │            ├SOLAR
              │            └MORE ──┬SWING ──┬AEINWT ── DATE1
              │                    │        ├EFM
              │                    │        ├MINMX3 ── (SEE CALL BY MAIN)
              └ PUNCH ──── EFM     │        ├SWTRAJ ──┬EFM
                                   │        └CONVER   ├TAPSET
                                   ├TAPSET            └TAP ── (SEE CALL BY TRAJ)
                                   ├TAP ── (SEE CALL BY TRAJ)
                                   ├EXTAB
                                   └EFMPRT-PDATE
```

*Entry Point

```
TRAJ  ┬TRAJI ──┬RIDGE*
      │        ├EFM
      │        ├RADAR ── EFM
      │        ├CHECKI* ─ STOREI*
      │        └SOLAR
      ├TAP ────┬THANG*
      │        ├THANGD
      │        ├SOLAR
      │        ├CHKINT* ┬CDERIV ───┬THANGD
      │        │        │          └RADAR ──┬EFM
      │        │        │                   └AEINWT
      ├EFM     │        ├LOAD ──── TRAVEL
      │        │        └STORE
      │        ├CONVRT
      │        ├DERIV ── SOLAR
      │        ├CDERIV ── (SEE ABOVE)
      ├ETA     ├FUNCT ── (SEE CALL FROM STEP)
      │        ├STEP ──┬RKSTEP ──┬PRIOR
      │        │       │         └DERIV ── SOLAR
      │        │       ├ANSTEP ──┬PRIOR
      │        │       │         └SCOMP
      │        │       └FUNCT ───┬THANGD
      │        │                 ├THANG*
      │        │                 └SOLAR
      │        ├CHECK ─┬CDERIV ── (SEE ABOVE)
      │        │       ├INTERP ──┬STEP ── (SEE ABOVE)
      │        │       │         └CDERIV ── (SEE ABOVE)
      │        │       ├LOAD ──── TRAVEL
      │        │       ├STORE
      │        │       ├STEP ──── (SEE ABOVE)
      │        │       ├STOREI*
      │        ├TRAVEL ├SOLAR
      │        │       └FUNCT ───┬THANGD
      │        │                 ├THANG*
      │        ├SPRINT ┬ALBEDO   └SOLAR
      │        │       ├SOLAR
      │        │       ├CARKEP
      │        │       ├EFM
      │        │       └PUNCH ── EFM
      │        └SWSTO ── SOLAR
      ├OMASS ──┬DECLIN
      │        ├GUNTHR
      │        └GET I ── GUNTHR
      ├RETINJ
      ├GET RV ─ INCOND
      ├GET Q
      ├VPRINT
      ├PRINT
      ├RIDGE*
      └PRINTR
```

*Entry Point

SUBROUTINE CROSS REFERENCE TABLE

NAME	SUBROUTINES REFERENCING MEMBER
AEINWT	QSTART RADAR SWING
ALBEDO	SPRINT
ANSTEP	IMPULS STEP
BEGIN	MAIN
BOOSTR	QPRINT QSTART
CARKEP	SPRINT
CCHECK	MINMX3
CDERIV	CHECK INTERP TAP
CHECK	TAP
CHECKI	TRAJI
CHKINT	TAP
CONVER	SWING
CONVRT	TAP
CORNER	FINISH MAIN
DATE1	AEINWT QSTART
DECLIN	CMASS PRINT
DERIV	RKSTEP TAP
EFM	ALBEDO PUNCH QSTART RADAR SPRINT SWING SWTRAJ TRAJ TRAJI
EFMPRT	MORE QPRINT
ETA	TRAJ
ETAINT	QSTART
EXTAB	FINISH MORE
FINISH	MAIN TIKTOK
FUNCT	CHECK STEP TAP
GETI	OMASS
GETQ	TRAJ
GETRV	TRAJ
GUESS	MAIN
GUNTHR	GETI OMASS
IMPULS	GUESS
INCOND	GETRV
INPUT	MAIN
INTERP	CHECK
LOAD	CHECK
MINMX3	GUESS MAIN SWING
MORE	QPRINT
OMASS	TRAJ
PARINC	MINMX3
PDATE	EFMPRT QPRINT
PD5	MINMX3
PMPINT	MINMX3
PMPRNT	MINMX3
PRINT	FINISH SOLAR TRAJ
PRINTR	FINISH SOLAR TRAJ
PRIOR	ANSTEP RKSTEP
PUNCH	FINISH SPRINT
QPRINT	FINISH QSTART
QSTART	MAIN
RADAR	CDERIV TRAJI

CROSS REFERENCE TABLE (CONTINUED)

NAME	SUBROUTINES REFERENCING MEMBER						
READER	MAIN						
REMTIM	TIKTOK						
RETINJ	TRAJ						
RIDGE	TRAJ	TRAJI					
RKSTEP	STEP						
SCOMP	ANSTEP	IMPULS					
SETUP	QSTART						
SIMEQ	GUESS	MINMX3					
SMQINT	GUESS	MINMX3					
SOLAR	CHECK	DERIV	FUNCT	QPRINT	SPRINT	SWSTO	TAP
	TRAJI						
SOLINT	QSTART						
SPRINT	INTERP	TAP					
STEP	CHECK	INTERP	TAP				
STORE	CHECK						
STOREI	CHECK						
SUMMRY	FINISH	TIKTOK					
SWING	MORE						
SWSTO	TAP						
SWTRAJ	SWING						
TAP	MORE	SWTRAJ	TRAJ				
TAPSET	MORE	SWTRAJ					
TFORM	SPRINT						
THANG	FUNCT	TAP					
THANGD	CDERIV	FUNCT	TAP				
TIKTOK	INPUT	MAIN	MINMX3				
TRAJ	FINISH	PARINC					
TRAJI	TRAJ						
TRAVEL	LOAD	TAP					
TRJINT	QSTART						
TWINKL	QSTART						
UNITD	CDERIV	THANGD					
VADD	CDERIV	TAP					
VCROSS	CARKEP	CDERIV	GETRV	INCOND	QPRINT	SPRINT	SWING
VDOT	ALBEDO	CARKEP	CDERIV	RADAR	SPRINT	SWING	
VMAG	ALBEDO	CARKEP	CDERIV	QPRINT	RADAR	SPRINT	SWING
	TAP						
VPRINT	TRAJ						
VSCAL	CDERIV	INCOND	SPRINT	SWING	TAP		
VSUB	ALBEDO	CDERIV	GETRV	SWING			

4. Common Array Information. Throughout the HILTOP program a total of 8 labelled common arrays are employed. In the tables to follow are presented cross-reference information sufficient to inform the user as to the occurrence of specific common arrays and of specific common variables throughout the program. The first table presents for each common array a list of all subroutines in which the named common appears. This is followed by separate tables for each common, containing subroutine references to each common variable. These tables list only variables that are actually referenced one or more times throughout the program. For each variable are listed the Fortran name, the type of variable (i.e., R*8 for double precision real, I*4 for integer, etc.), the address of the variable in decimal bytes relative to the start of the common, and the name of the subroutine in which the variable appears. A separate line appears for each subroutine in which the variable is referenced. For the second and subsequent subroutine references, no other information is repeated unless the Fortran name of the variable is different, in which case the new name and the relative address are repeated. The definition of any referenced common variable is given in the External Variables Table of the subroutine referencing the variable.

COMMON CROSS REFERENCE TABLE

NAME	SUBROUTINES REFERENCING MEMBER						
EXTREM	BEGIN	CDERIV	CHECK	EXTAB	INTERP	LOAD	PRINT
	STORE	TAP					
GUNCOM	GETI	GETQ	GUNTHR	OMASS			
INTGR4	BEGIN	CDERIV	CHECK	CORNER	DERIV	EFMPRT	EXTAB
	FINISH	GETQ	INPUT	INTERP	LOAD	MAIN	MINMX3
	MORE	PARINC	PRINT	PRINTR	PRIOR	PUNCH	QPRINT
	QSTART	RADAR	RKSTEP	SETUP	SOLAR	SPRINT	STORE
	SUMMRY	SWING	SWSTO	SWTRAJ	TAP	TAPSET	TIKTOK
	TRAJ	TRAJI					
ITERAT	BEGIN	CDERIV	CORNER	FINISH	GETQ	GETRV	GUESS
	INPUT	MINMX3	OMASS	PARINC	PRINT	PRINTR	PUNCH
	QPRINT	QSTART	RADAR	SETUP	SOLAR	SPRINT	SWING
	TAP	TRAJ	TRAJI	VPRINT			
ITER2	BEGIN	GETQ	GUESS	IMPULS	MINMX3	PARINC	PRINTR
	QSTART	SWING	SWTRAJ	TIKTOK	TRAJI		
LOGIC4	BEGIN	CDERIV	CHECK	CORNER	DECLIN	DERIV	EXTAB
	FINISH	FUNCT	GETI	GETQ	GETRV	INTERP	LOAD
	MAIN	MINMX3	MORE	OMASS	PARINC	PRINT	PRINTR
	PRIOR	PUNCH	QPRINT	QSTART	RADAR	RETINJ	RKSTEP
	SETUP	SOLAR	SPRINT	STEP	STORE	SUMMRY	SWING
	SWSTO	TAP	TAPSET	THANGD	TIKTOK	TRAJ	TRAJI
REAL8	ALBEDO	ANSTEP	BEGIN	CDERIV	CHECK	CONVRT	CORNER
	DECLIN	DERIV	EFM	EFMPRT	ETA	EXTAB	FINISH
	FUNCT	GETI	GETQ	GETRV	GUESS	IMPRNT	IMPULS
	INPUT	INTERP	LOAD	MAIN	MINMX3	MORE	OMASS
	PRINT	PRINTR	PRIOR	PUNCH	QPRINT	QSTART	RADAR
	RETINJ	RKSTEP	SOLAR	SPRINT	STORE	SUMMRY	SWING
	SWSTO	SWTRAJ	TAP	TAPSET	THANGD	TIKTOK	TRAJ
	TRAJI	TRAVEL	TWINKL	VPRINT			
SOLSYS	BEGIN	EFM	EFMPRT	MORE	QPRINT	QSTART	SPRINT
	SWING	TRAJ					

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON ITER2 LENGTH 12880

VARIABLE	TYPE	ADDR	SUBROUTINE
B	R*8	0	GUESS
			SWING
			TRAJI
			IMPULS
			MINMX3
			PARINC
			QSTART
			SATRAJ
			TIKTOK
PDI	R*8	0	BEGIN
Q	R*8	280	GETQ
			SWING
			IMPULS
			MINMX3
			PARINC
			SWTRAJ
BS	R*8	560	GUESS
			SWING
			MINMX3
			QSTART
BW	R*8	840	GUESS
			SWING
			MINMX3
			QSTART
QMIN	R*8	1120	GUESS
			SWING
			MINMX3
			PRINTR
			QSTART
QMAX	R*8	1400	GUESS
			SWING
			MINMX3
			PRINTR
			QSTART
BB	R*8	1680	PARINC
BBB	R*8	1680	GUESS
			SWING
			MINMX3
			QSTART
YYY	R*8	1960	MINMX3
BNDMX	R*8	2240	MINMX3
			TIKTOK
PM	R*8	2520	GUESS
			MINMX3

ORIGINAL PAGE IS OF POOR QUALITY

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON REAL8 LENGTH 15000

VARIABLE	TYPE	ADDR	SUBROUTINE
R01	R*8	0	BEGIN
SAVE	R*8	0	SUMMRY
PAYLOD	R*8	0	GETQ
			TRAJ
			PRINT
			PUNCH
			PRINTR
			QPRINT
AM	R*8	8	OMASS
XMASS	R*8	8	GETQ
			TRAJ
			EXTAB
			PRINT
			PUNCH
			PRINTR
			QPRINT
			RETINJ
			TAPSET
CTANK	R*8	72	TRAJ
			BEGIN
			INPUT
			PUNCH
			QPRINT
CSTR	R*8	80	TRAJ
			INPUT
			PUNCH
			QPRINT
FT	R*8	88	TAP
			GETQ
			DERIV
			FUNCT
			SOLAR
			SWSTO
			TRAJI
			CDERIV
			QSTART
			RETINJ
			SPRINT
VJ	R*8	96	GETQ
			TRAJ
			SOLAR
			TRAJI
			CDERIV
			QSTART
			RETINJ
			VPRINT
VIMP	R*8	104	TRAJ
			TRAJI

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			DECLIN
			QPRINT
			QSTART
OTMASS	R*8	112	TRAJ
			PUNCH
			QPRINT
			RETINJ
DMRETR	R*8	152	INPUT
			PUNCH
			RETINJ
CTRET	R*8	160	TRAJ
			BEGIN
			INPUT
			PUNCH
RPER	R*8	168	BEGIN
			INPUT
			PUNCH
			QPRINT
			RETINJ
RAP	R*8	176	BEGIN
			INPUT
			PUNCH
			QPRINT
			RETINJ
THRET	R*8	184	BEGIN
			INPUT
			PUNCH
			QPRINT
			RETINJ
SPIRET	R*8	192	BEGIN
			INPUT
			PUNCH
			QPRINT
			RETINJ
DVEL	R*8	200	PUNCH
			QPRINT
			RETINJ
VLOSS	R*8	208	TRAJ
			PUNCH
			QPRINT
			RETINJ
VORB	R*8	216	PUNCH
			QPRINT
			RETINJ
ASOL	R*8	224	INPUT
			SOLAR
XJLD	R*8	264	QPRINT
TRIP	R*8	272	PUNCH
			QPRINT
PT	R*8	288	PUNCH
			QPRINT

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
F	R*8	296	PUNCH
FFF	R*8	296	OPRINT
PARM	R*8	304	PUNCH
			OPRINT
FMAX	R*8	312	PUNCH
			OPRINT
ANGD	R*8	320	PUNCH
			OPRINT
HOUR	R*8	328	BEGIN
			INPUT
			PUNCH
			QSTART
TPMAX	R*8	336	BEGIN
AAI	R*8	344	INPUT
			PUNCH
			QSTART
STATE	R*8	352	MAIN
			BEGIN
			INPUT
			PUNCH
			QSTART
XO	R*8	400	GETQ
			TRAJ
			BEGIN
			GETRV
			GUESS
			INPUT
			PUNCH
			RADAR
			TRAJI
			OPRINT
			QSTART
PO	R*8	456	GETQ
			TRAJ
			GUESS
			TRAJI
BI	R*8	512	BEGIN
			INPUT
			PUNCH
			OPRINT
			QSTART
DI	R*8	520	BEGIN
			INPUT
			PUNCH
			OPRINT
			QSTART
EI	R*8	528	INPUT
			PUNCH
			OPRINT
			QSTART
B1	R*8	536	INPUT

ORIGINAL PAGE IS OF POOR QUALITY

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			PUNCH
			QPRINT
			QSTART
B2	R*8	544	INPUT
			PUNCH
			QPRINT
			QSTART
B3	R*8	552	INPUT
			PUNCH
			QPRINT
			QSTART
PDAFIX	R*8	560	TRAJ
			BEGIN
			INPUT
			PUNCH
			QSTART
AR	R*8	568	BEGIN
			GETRV
			INPUT
			PUNCH
			QSTART
AV	R*8	576	GETRV
			QSTART
AI	R*8	584	GETRV
			QSTART
SI	R*8	592	GETRV
			QSTART
CI	R*8	600	GETRV
			QSTART
AE	R*8	608	INPUT
			PUNCH
			QSTART
SAI	R*8	616	EFM
			BEGIN
			INPUT
			PUNCH
			QPRINT
			QSTART
ECI	R*8	624	EFM
			INPUT
			PUNCH
			QSTART
CNI	R*8	632	EFM
			INPUT
			PUNCH
			QSTART
OMI	R*8	640	EFM
			INPUT
			PUNCH
			QSTART
SOI	R*8	648	EFM

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			INPUT
			PUNCH
			QSTART
TPI	R*8	656	EFM
			INPUT
			PUNCH
			OPRINT
			OSTART
EMUODD	R*8	664	EFM
			TRAJ
			INPUT
			PUNCH
			SWING
			OSTART
RADODD	R*8	672	TRAJ
			BEGIN
			INPUT
			PUNCH
			SWING
			OSTART
DBETA	R*8	680	TAP
			CHECK
			INTERP
STEP1	R*8	688	TAP
			BEGIN
			INPUT
			PUNCH
STEP2	R*8	696	TAP
			BEGIN
			INPUT
			PUNCH
TMAX	R*8	704	TAP
			GETD
			TRAJ
			GUESS
			TRAJI
			IMPULS
			QSTART
			SWTRAJ
			TAPSET
T2	R*8	712	MORE
			BEGIN
			INPUT
GOO	R*8	792	SWING
			SWTRAJ
TDV	R*8	800	TAP
			GETD
			BEGIN
			INPUT
			OSTART
TDELV	R*8	808	TAP

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			QSTART
GAP	R*8	816	BEGIN
			CHECK
			INPUT
			FINISH
			QSTART
			TIKTOK
THUNG	R*8	824	CHECK
			CORNER
SYHUNG	R*8	864	CHECK
			CORNER
HOHUNG	R*8	904	CHECK
			CORNER
XCOM	R*8	944	LOAD
			CHECK
			RADAR
			CDERIV
GLARE	R*8	992	LOAD
			RADAR
SEFMA	R*8	1000	GETD
			TRAJ
			TRAJI
			QPRINT
			QSTART
SEFMB	R*8	1056	GETD
			TRAJ
			TRAJI
			QPRINT
			QSTART
SEFMC	R*8	1112	GETD
			TRAJ
			TRAJI
			QSTART
SEFMD	R*8	1168	GETD
			TRAJ
			TRAJI
			QSTART
ANGLE	R*8	1224	TAP
			LOAD
			PRINT
			TRAJI
			QPRINT
			SPRINT
			TAPSET
TBURN	R*8	1232	PUNCH
			QPRINT
TDATE1	R*8	1240	TRAJ
			PUNCH
			TRAJI
			QPRINT
			QSTART

COMMON REALS (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
TDATE2	R*8	1248	MORE
			TRAJ
			SWING
			TRAJI
			QPRINT
			QSTART
TDATEX	R*8	1256	EFM
			TRAJ
			PUNCH
			RADAR
			SWING
			TRAJI
			QPRINT
			QSTART
			SPRINT
SRA	R*8	1264	TWINKL
SDC	R*8	1272	TWINKL
SPV	R*8	1280	SPRINT
			TWINKL
TANGLE	R*8	1304	LOAD
			TRAJI
			TAPSET
			TRAVEL
AAA	R*8	1312	GETI
			OMASS
BBB	R*8	1320	GETI
			OMASS
CCC	R*8	1328	OMASS
ANG1	R*8	1336	GETI
			OMASS
			PUNCH
			TRAJI
			QPRINT
ANG2	R*8	1344	OMASS
			PUNCH
			QPRINT
E	R*8	1352	BEGIN
SE	R*8	1360	GETQ
			BEGIN
			TRAJI
			DECLIN
			TWINKL
CE	R*8	1368	GETQ
			BEGIN
			TRAJI
			DECLIN
			TWINKL
DECL	R*8	1376	GETQ
			OMASS
			PRINT
			PUNCH

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			DECLIN
			QPRINT
AIS	R*8	1384	TAP
			FUNCT
			SOLAR
XINCL	R*8	1392	OMASS
			PUNCH
			QPRINT
ALTAU	R*8	1400	TAP
			GETD
			FUNCT
			SWSTD
			TRAJI
			SPRINT
			TAPSET
TGO	R*8	1408	MORE
			BEGIN
			INPUT
RMAX	R*8	1416	CHECK
			PRINT
			PUNCH
			STORE
			QPRINT
RMIN	R*8	1424	CHECK
			PRINT
			PUNCH
			STORE
			QPRINT
PMAX	R*8	1432	CHECK
			STORE
			QPRINT
COMOIS	R*8	1440	EXTAB
			PUNCH
			TAPSET
COMANG	R*8	1448	EXTAB
			PUNCH
			TAPSET
RTSWIT	R*8	1456	TAP
			EXTAB
			CDERIV
			QSTART
			SPRINT
PSI	R*8	1464	LOAD
			CDERIV
			SPRINT
THETA	R*8	1472	LOAD
			CDERIV
			SPRINT
PHI	R*8	1480	LOAD
			CDERIV
			SPRINT

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
GPLAN	R*8	1488	GETD
			TRAJ
			RETINJ
RPLAN	R*8	1496	TRAJ
			RETINJ
SPISPY	R*8	1504	QPRINT
			RETINJ
THSPY	R*8	1512	QPRINT
			RETINJ
TIMSPY	R*8	1520	QPRINT
			RETINJ
XMSPY	R*8	1528	QPRINT
			RETINJ
EVC	R*8	1536	RADAR
			CDERIV
XANG1	R*8	1584	INPUT
			OMASS
XANG2	R*8	1592	INPUT
			OMASS
R	R*8	1600	TAP
			GETD
			LOAD
			TRAJ
			FUNCT
			PUNCH
			CDERIV
			CONVRT
			QPRINT
			SPRINT
PP	R*8	1616	TAP
			CHECK
			FUNCT
			CDERIV
SWITCH	R*8	1632	TAP
			GETD
			LOAD
			CHECK
			FUNCT
			CDERIV
			SPRINT
DWITCH	R*8	1648	TAP
			FUNCT
			CDERIV
			VPRINT
SAIX	R*8	1800	EFM
			INPUT
			RADAR
			SWING
			QSTART
ECIX	R*8	1840	EFM
			INPUT

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			RADAR
			SWING
			QSTART
CNIX	R*8	1880	EFM
			INPUT
			RADAR
			SWING
			QSTART
CMIX	R*8	1920	EFM
			INPUT
			RADAR
			SWING
			QSTART
SOIX	R*8	1960	EFM
			INPUT
			RADAR
			SWING
			QSTART
TPIX	R*8	2000	EFM
			INPUT
			RADAR
			SWING
			QSTART
EMUODX	R*8	2040	EFM
			INPUT
			RADAR
			SWING
			QSTART
RADODX	R*8	2080	INPUT
			RADAR
			SWING
			QSTART
ALPHAA	R*8	2120	TRAJ
			BEGIN
			INPUT
			PUNCH
			QPRINT
ALPHAT	R*8	2128	TRAJ
			BEGIN
			INPUT
			PUNCH
			QPRINT
AN	R*8	2400	TAP
			BEGIN
			DERIV
			INPUT
			PUNCH
			CONVRT
RIN	R*8	2408	TAP
			DERIV
			CDERIV

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			CONVRT
P2N	R*8	2416	TAP
			DERIV
VOOD	R*8	2424	GETQ
			GETRV
			TRAJI
			DECLIN
			QPRINT
PIMD	R*8	2448	GETQ
			TRAJ
PSIGN	R*8	2456	GETQ
			TRAJ
			BEGIN
			INPUT
			PRINT
			TRAJI
TSCALE	R*8	2464	BEGIN
			INPUT
			QSTART
DECLAM	R*8	2472	PRINT
			TRAJI
REVS	R*8	2480	GUESS
			INPUT
XAMBDA	R*8	2488	PRINT
			MINMX3
			PRINTR
DEG	R*8	2496	EFM
			GETI
			GETQ
			LOAD
			BEGIN
			DMASS
			PRINT
			PUNCH
			SWING
			ALBEDO
			EFMPRT
			QPRINT
			QSTART
			SPRINT
			TWINK_
FPSNMH	R*8	2504	GETQ
			BEGIN
			QSTART
			VPRINT
SUNMU	R*8	2512	EFM
			TRAJ
			BEGIN
			QSTART
CONTM	R*8	2520	TAP
			GETQ

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			LOAD
			TRAJ
			BEGIN
			CHECK
			PRINT
			PUNCH
			RADAR
			SOLAR
			SWING
			SWSTD
			TRAJI
			CORNER
			INTERP
			OPRINT
			OSTART
			SPRINT
			SWTRAJ
			TAPSET
CONSP	R*8	2528	ETA
			TAP
			GETQ
			BEGIN
			DMASS
			SWING
			EFMPRT
			OPRINT
			RETINJ
			SPRINT
CONAQ	R*8	2536	GETQ
			BEGIN
			RETINJ
CONPW	R*8	2544	TRAJ
			BEGIN
PI	R*8	2552	BEGIN
			RADAR
TWOPI	R*8	2560	EFM
			BEGIN
CONDS	R*8	2568	BEGIN
			EPRINT
CONLBS	R*8	2576	BEGIN
			RETINJ
CONG	R*8	2584	BEGIN
			RETINJ
DELTAV	R*8	2592	TAP
			GETQ
XSWING	R*8	2600	MORE
			INPUT
YSWING	R*8	3040	MORE
			SWING
TOFF	R*8	4200	TRAJ
			BEGIN

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			INPUT
			QPRINT
			QSTART
TCUAST	R*8	4360	TRAJ
			INPUT
			QPRINT
TCHECK	R*8	4520	TAP
			TRAJ
			CHECK
			CDERIV
			TAPSET
F	R*8	5160	GUESS
			ANSTEP
G	R*8	5168	ANSTEP
FX	R*8	5176	GUESS
			ANSTEP
GX	R*8	5224	GUESS
			ANSTEP
ER	R*8	5448	QSTART
ERD	R*8	5472	QSTART
EN	R*8	5496	QSTART
END	R*8	5520	QSTART
AXIS	R*8	5544	DERIV
			QSTART
AXISD	R*8	5568	QSTART
ALTITU	R*8	5592	GETQ
			INPUT
			QSTART
			VPRINT
TSW	R*8	5600	SWSTQ
			PRINTR
HSW	R*8	6000	SWSTQ
PVELOC	R*8	6400	SWING
			SWTRAJ
TBASE	R*8	6424	SWING
			SWTRAJ
TSUM	R*8	6432	MORE
			SWING
			SWTRAJ
ZSTATE	R*8	6440	SWING
			SWTRAJ
ETH	R*8	6600	TAP
			DERIV
			FUNCT
			SWSTQ
			CDERIV
			QSTART
			SPRINT
			THANGQ
ETHD	R*8	6624	TAP
			FUNCT

COMMON REALS (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			CDERIV
			QSTART
			SPRINT
			THANGD
SWIT	R*8	6720	TAP
			CHECK
			DERIV
			FUNCT
			CDERIV
SIPHI	R*8	6728	TAP
			DERIV
			CDERIV
			THANGD
COPHI	R*8	6736	TAP
			DERIV
			CDERIV
			THANGD
PLC	R*8	6744	TAP
			DERIV
			FUNCT
			SWSTD
			SPRINT
HAM	R*8	6760	TAP
			TRAJ
HAMX	R*8	6768	GETD
			TRAJ
ETHSW	R*8	6800	SWSTD
XJLA	R*8	8000	QPRINT
HOURD	R*8	8008	QPRINT
HOURA	R*8	8016	QPRINT
C3	R*8	8024	QPRINT
C4	R*8	8032	QPRINT
DEP	R*8	8040	QPRINT
ARR	R*8	8048	QPRINT
XSP	R*8	8056	QPRINT
DPOW	R*8	9056	TRAJ
			INPUT
			SOLAR
			QPRINT
GAMMAX	R*8	9064	BEGIN
			INPUT
			SOLAR
DMIN	R*8	9072	CHECK
			SOLAR
DPDMAX	R*8	9080	TAP
			SOLAR
CHFNC2	R*8	9088	SOLAR
			CDERIV
CHFNC	R*8	9112	CHECK
			SOLAR
			TRAJI

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			CDERIV
SAMPS	R*8	9120	TRAJ
			OPRINT
DROPS	R*8	9128	TRAJ
			OPRINT
PMDOT	R*8	9136	TAP
			FUNCT
			CDERIV
PMN	R*8	9160	TAP
			GETD
			TRAJ
			DERIV
			FUNCT
			SOLAR
			TRAJI
PMS	R*8	9168	TRAJ
			DERIV
			FUNCT
			TRAJI
RT	R*8	9176	TAP
			DERIV
			FUNCT
			SOLAR
			SWSTD
			TRAJI
			ANSTEP
			OPRINT
			SPRINT
RS	R*8	9184	DERIV
			SWSTD
RC	R*8	9192	TAP
			DERIV
			FUNCT
			SWSTD
			ANSTEP
			SPRINT
ACC	R*8	9200	DERIV
			FUNCT
AMD	R*8	9208	CMASS
FMS	R*8	9208	GETD
			TRAJ
POWR	R*8	9232	TAP
			LOAD
			DERIV
			FUNCT
			SOLAR
			SWSTD
			CDERIV
			OPRINT
			RETINJ
			SPRINT

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
DPOWR	R*8	9240	TAP
			DERIV
			FUNCT
			SOLAR
			CDERIV
			SPRINT
TAUPOW	R*8	9248	TAP
			DERIV
			FUNCT
			SOLAR
			CDERIV
DMASS	R*8	9256	DERIV
DMDVC	R*8	9264	GETQ
			OMASS
AM	R*8	9272	GETQ
			RETINJ
EX	R*8	9280	TRAJ
			RETINJ
FP	R*8	9288	TRAJ
			RETINJ
GCST	R*8	9296	TRAJ
			RETINJ
VH	R*8	9304	GETQ
			TRAJ
			RETINJ
VHS	R*8	9312	TRAJ
			RETINJ
VINF	R*8	9320	GETQ
			TRAJ
			RETINJ
VJRET	R*8	9328	TRAJ
			RETINJ
VS	R*8	9336	TRAJ
			RETINJ
XLONG	R*8	9344	QSTART
YLONG	R*8	9344	SPRINT
AVJ	R*8	9352	TAP
			TRAJ
			DERIV
			FUNCT
			SWSTQ
			TRAJI
			SPRINT
FTVJ	R*8	9360	TRAJ
			TRAJI
FTOVJ	R*8	9368	DERIV
			TRAJI
FMSI	R*8	9376	GETQ
			TRAJ
			OMASS
SKOUNT	R*8	9384	LOAD

COMMON REALS (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			CHECK
			INTERP
DMAX	R*8	9392	SOLAR
			SPRINT
AK	R*8	9400	GETQ
			TRAJ
D	R*8	9408	CDERIV
DENSIT	R*8	9408	TAP
			LOAD
			DERIV
			FUNCT
			SOLAR
			SWSTQ
			SPRINT
PMD	R*8	9416	GETQ
			TRAJ
PMOD	R*8	9424	GETQ
			TRAJ
			TRAJI
TEST	R*8	9432	TRAJ
			TRAJI
GSUBX	R*8	9440	GETQ
			TRAJ
TEMP2	R*8	9448	GETQ
			TRAJ
DPOWDD	R*8	9456	TAP
			FUNCT
			SOLAR
			CDERIV
TEMP4	R*8	9464	GETQ
			TRAJ
AJT	R*8	9472	TRAJ
AJPP	R*8	9480	GETQ
			TRAJ
FETA	R*8	9488	GETQ
			TRAJ
SCALE	R*8	9496	GETQ
			TRAJ
TPOWER	R*8	9504	BEGIN
			INPUT
			SOLAR
			QPRINT
DEGRAD	R*8	9512	FUNCT
			SOLAR
			SPRINT
PMAXO	R*8	9520	SOLAR
RPMAXO	R*8	9528	SOLAR
			QSTART
RPOWO	R*8	9536	SOLAR
			QSTART
DPOWD	R*8	9544	SOLAR

COMMON REALS (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			CDERIV
			SPRINT
WPRIM	R*8	9552	GETQ
			TRAJ
SX	R*8	9600	TAP
			LOAD
			GUESS
			PRIOR
			ANSTEP
			IMPRNT
			IMPULS
			INTERP
			QSTART
			RKSTEP
X	R*8	10000	TAP
			GETQ
			LOAD
			MORE
			TRAJ
			CHECK
			DERIV
			FUNCT
			GETRV
			GUESS
			PRIOR
			PUNCH
			RADAR
			SOLAR
			SWING
			SWSTD
			TRAJI
			ANSTEP
			CDERIV
			CONVRT
			IMPRNT
			IMPULS
			INTERP
			QPRINT
			QSTART
			RKSTEP
			SPRINT
			SWTRAJ
			TAPSET
			VPRINT
XD	R*8	10400	TRAJ
			DERIV
			FUNCT
			PRIOR
			ANSTEP
			CDERIV
			QSTART

COMMON REAL8 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			RKSTEP
			SPRINT
SBETA	R*8	1080C	PRIOR
			ANSTEP
			INTERP
			RKSTEP
BETA	R*8	10808	CHECK
			PRIOR
			TRAJI
			ANSTEP
			CDERIV
			RKSTEP
			TAPSET
STAU	R*8	10816	PRIOR
			RKSTEP
TAU	R*8	10824	GETQ
			PRINT
			PRIOR
			PUNCH
			TRAJI
			PRINTR
			QPRINT
			RKSTEP
			SPRINT
XINT	R*8	11000	GETQ
			TRAJ
			QPRINT
XDINT	R*8	13000	TRAJ
XTINT	R*8	15000	GETQ
			TRAJ
			QPRINT
XTDINT	R*8	15240	GETQ
			TRAJ

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON EXTREM LENGTH 21760

VARIABLE	TYPE	ADDR	SUBROUTINE
E01	R*8	0	BEGIN
TIME	R*8	0	EXTAB
			STORE
TRAV	R*8	800	EXTAB
			STORE
DIST	R*8	1600	EXTAB
			STORE
ONOFF	R*8	3200	EXTAB
			PRINT
			STORE
DISCOM	R*8	4800	EXTAB
			STORE
ANGCOM	R*8	6400	EXTAB
			STORE
ANGPSI	R*8	8000	EXTAB
			STORE
ANGTHE	R*8	9600	EXTAB
			STORE
ANGPHI	R*8	11200	EXTAB
			STORE
POWEX	R*8	12800	EXTAB
			STORE
CHIX	R*8	14400	CHECK
			EXTAB
			STORE
AKOUNT	R*8	16000	EXTAB
			STORE
CEPS	R*8	16800	LOAD
			CHECK
			STORE
B	R*8	21280	TAP
			LOAD
			CHECK
			CDERIV
			INTERP

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON GUNCOM LENGTH 64

VARIABLE	TYPE	ADDR	SUBROUTINE
V0	R*8	0	OMASS
			GUNTHR
V0DIV	R*8	8	OMASS
			GUNTHR
V00	R*8	16	GETI
			OMASS
			GUNTHR
I00	R*8	24	GETI
			OMASS
			GUNTHR
DV	R*8	32	OMASS
			GUNTHR
DVV00	R*8	40	OMASS
			GUNTHR
DVI00	R*8	48	GETI
			GETO
			OMASS
			GUNTHR
GL1	L*4	56	GETO
LDVV00	L*4	56	GETI
			OMASS
			GUNTHR
LDVI00	L*4	60	GETI
			OMASS
			GUNTHR

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON INTGR4 LENGTH 4000

VARIABLE	TYPE	ADDR	SUBROUTINE
IRL	I*4	0	BEGIN
			INPUT
			QSTART
ISAVE	I*4	0	SUMMRY
MODE	I*4	4	TAP
			LOAD
			BEGIN
			CHECK
			EXTAB
			INPUT
			PUNCH
			SOLAR
			QSTART
IRK	I*4	8	BEGIN
			INPUT
			PUNCH
ITF	I*4	12	BEGIN
			INPUT
			TIKTOK
LINE	I*4	16	PRINT
			SOLAR
			MINMX3
			QSTART
JPRINT	I*4	20	TRAJ
			INPUT
MBOOST	I*4	24	INPUT
			PUNCH
			QPRINT
			QSTART
MOPT	I*4	28	MAIN
			INPUT
			PUNCH
			CORNER
NTAPE	I*4	32	BEGIN
			INPUT
			PUNCH
			QSTART
MDAY	I*4	36	BEGIN
			INPUT
			PUNCH
			QSTART
MONTH	I*4	40	BEGIN
			INPUT
			PUNCH
			QSTART
MYEAR	I*4	44	BEGIN
			INPUT
			PUNCH

COMMON INTGR4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			QSTART
MREAD	I*4	48	MAIN
			INPUT
			CORNER
MUPDAT	I*4	52	BEGIN
			INPUT
			CORNER
			FINISH
MPRINT	I*4	56	INPUT
			FINISH
			QSTART
NSET	I*4	60	MAIN
			BEGIN
			INPUT
			PRINT
			PRINTR
			QPRINT
			QSTART
IROT	I*4	80	INPUT
			PUNCH
			CORNER
			QSTART
JPP	I*4	84	TRAJ
			INPUT
			PUNCH
			QPRINT
JT	I*4	88	TRAJ
			INPUT
			PUNCH
			QPRINT
MOPT2	I*4	92	TRAJ
			INPUT
			PUNCH
			TRAJI
			EFMPRT
			QPRINT
			QSTART
			SPRINT
MOPT3	I*4	96	MORE
			TRAJ
			BEGIN
			INPUT
			PUNCH
			TRAJI
			QPRINT
			QSTART
			SPRINT
			TAPSET
MOPT4	I*4	100	MORE
			INPUT
NTARG	I*4	140	SWING

COMMON INTGR4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			SWTRAJ
MTMASS	I*4	144	INPUT
			PUNCH
			QPRINT
			QSTART
NSPEC	I*4	148	CHECK
			EXTAB
			PRINT
			STORE
			TRAJI
			TAPSET
MPUNCH	I*4	156	INPUT
			PUNCH
			FINISH
			INTERP
			QSTART
			SPRINT
LCOUNT	I*4	160	QSTART
			SPRINT
NPRINT	I*4	164	TAP
			TRAJ
			BEGIN
			INPUT
			PRINTR
			QSTART
NPR	I*4	168	FINISH
			MINMX3
			QPRINT
			QSTART
NSWPAR	I*4	184	BEGIN
			INPUT
			MINMX3
NORMAL	I*4	188	INPUT
			QSTART
LIMPHI	I*4	192	GETQ
			SETUP
			TRAJI
KPART	I*4	196	MAIN
			INPUT
			CORNER
IHUNG	I*4	200	TRAJ
			CHECK
			CORNER
NHUNG	I*4	204	BEGIN
			INPUT
			CORNER
KOUNT	I*4	212	MAIN
			EXTAB
			PRINT
			PUNCH
			CORNER

COMMON INTGR4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			EFMPRT
			FINISH
			QPRINT
			QSTART
			SPRINT
			TIKTOK
IBAL	I*4	216	INPUT
			PUNCH
			QSTART
MYEARD	I*4	220	QPRINT
MYEARA	I*4	224	QPRINT
MOND	I*4	228	QPRINT
MONA	I*4	232	QPRINT
MDAYD	I*4	236	QPRINT
MDAYA	I*4	240	QPRINT
LXX	I*4	244	TRAJ1
			QPRINT
			QSTART
			TIKTOK
MXX	I*4	248	GETD
			QPRINT
			QSTART
JJ	I*4	252	TAP
			CHECK
KF	I*4	256	TAP
			CHECK
JHUNG	I*4	260	MAIN
			CORNER
			FINISH
			TIKTOK
MAJOR	I*4	264	TRAJ
			PRINT
			MINMX3
			PRINTR
			TIKTOK
MAJORS	I*4	268	MINMX3
			PRINTR
			TIKTOK
MINOR	I*4	272	MINMX3
			PRINTR
LAUNCH	I*4	276	INPUT
			PUNCH
			SETUP
			QSTART
ISTAR	I*4	280	PUNCH
IEND	I*4	284	PUNCH
			SPRINT
ISPIN	I*4	288	INPUT
			SCLAR
IOUT	I*4	292	GETD
			INPUT

COMMON INTGR4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			PRINTR
			OSTART
NSW	I*4	296	PRINT
			SWSTD
			TRAJI
			MINMX3
			PRINTR
			TAPSET
ISW	I*4	300	SWSTD
			PRINTR
INTPR	I*4	500	INPUT
			INTERP
LEG	I*4	504	TRAJ
			SPRINT
			TAPSET
LEGMAX	I*4	508	GET2
			TRAJ
			SETUP
			EFMPRT
			PRINTR
			OPRINT
			OSTART
			SPRINT
			TAPSET
MOPTX	I*4	512	TRAJ
			INPUT
			OPRINT
			OSTART
			SPRINT
			TAPSET
INTER	I*4	532	TRAJ
			OSTART
			SPRINT
LOADX	I*4	552	INPUT
			OSTART
MPOW	I*4	556	EXTAB
			INPUT
			OPRINT
			OSTART
NSWING	I*4	560	MORE
			INPUT
NDIST	I*4	564	BEGIN
			INPUT
			RADAR
NPERF	I*4	568	INPUT
			OSTART
MPERF	I*4	572	MAIN
			OSTART
ITPRNT	I*4	576	INPUT
			MINMX3
INTERX	I*4	580	MORE

COMMON INTGR4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			SWING
			SPRINT
			SWTRAJ
MAXHAM	I*4	584	BEGIN
			INPUT
			SWSTD
NLEAVE	I*4	588	SWING
			SWTRAJ
MSWING	I*4	592	MORE
			INPUT
LL	I*4	740	TRAJI
			PARINC
			QSTART
MM	I*4	1020	GETQ
			MINMX3
			QSTART
NPHI	I*4	1300	TAP
NPHI20	I*4	1304	TAP
			DERIV
			PRIOR
			RKSTEP
NCHK	I*4	1308	CHECK
NCEP	I*4	1312	LOAD
			CHECK
			STORE
NSTEP1	I*4	1316	TAP
			PRINT
			TRAJI
NSTEP2	I*4	1320	TAP
			PRINT
			TRAJI
JC	I*4	1324	TAP
			LOAD
			TRAJ
			CHECK
			CDERIV
			TAPSET
JCMAX	I*4	1328	TAP
			LOAD
			TRAJ
			CHECK
			TAPSET
NSWX	I*4	1400	PRINT
			MINMX3

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON ITERAT LENGTH 7540

VARIABLE	TYPE	ADDR	SUBROUTINE
BX	R*8	0	TRAJ
			BEGIN
			GUESS
			INPUT
			PRINT
			PUNCH
			SETUP
			CORNER
			FINISH
			PARINC
			QPRINT
			QSTART
BY	R*8	2800	BEGIN
			INPUT
			SETUP
			CORNER
			PRINTR
			QPRINT
			QSTART
CONX	R*8	4480	GETQ
			TRAJ
			BEGIN
			GUESS
			SOLAR
			FINISH
			PARINC
			PRINTR
			QSTART
CONY	R*8	5040	BEGIN
			PRINT
			PRINTR
			QSTART
Q	R*8	5600	TAP
			GETQ
			TRAJ
			GETRV
			OMASS
			RADAR
			SOLAR
			TRAJI
			CDERIV
			FINISH
			PRINTR
			QPRINT
			QSTART
			SPRINT
			VPRINT
QQ	R*8	6160	TRAJ

COMMON ITERAT (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			PRINT
			PUNCH
			SOLAR
			SWING
			FINISH
			OPRINT
FXL	R*8	6720	GETQ
			PRINT
			PRINTR
			OSTART
FXL1	R*8	7280	MINMX3
			PRINTR

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON LOGIC4 LENGTH 2003

VARIABLE	TYPE	ADDR	SUBROUTINE
ERROR	L*4	0	TAP
			GETI
			MAIN
			BEGIN
			CHECK
			PUNCH
			SOLAR
			SWSTD
			FINISH
			QPRINT
			SUMMRY
			TIKTOK
ERRORX	L*4	0	TRAJ
			TRAJI
CONVRG	L*4	4	MAIN
			BEGIN
			PUNCH
			FINISH
			QPRINT
			QSTART
			SUMMRY
			TIKTOK
FALSE	L*4	8	BEGIN
FIXPOW	L*4	8	GETD
			TRAJ
			PRINT
			QPRINT
			QSTART
QPR	L*4	12	MAIN
			QSTART
WONDER	L*4	16	TRAJ
			CHECK
			MINMX3
			PARINC
			QSTART
HUNG	L*4	20	CORNER
			FINISH
			MINMX3
PARNSW	L*4	24	MINMX3
QDECL	L*4	28	DMASS
			PRINT
			TRAJI
			QPRINT
			QSTART
TUDFLG	L*4	32	TAP
			CHECK
			DERIV
			PRIOR

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			RADAR
			DECLIN
			QSTART
			THANGD
OUTECL	L*4	36	GETQ
			TRAJ
			RADAR
			TRAJI
			QPRINT
			QSTART
			SPRINT
FIXTHR	L*4	40	TAP
			GETQ
			CHECK
			DERIV
			FUNCT
			PRIOR
			TRAJI
			CDERIV
			QPRINT
			QSTART
			RKSTEP
			SPRINT
QVLOSS	L*4	44	TRAJ
			QSTART
FLYBY	L*4	48	GETQ
			TRAJ
			QPRINT
			QSTART
			RETINJ
BRAKE	L*4	52	QPRINT
			QSTART
RENDEZ	L*4	56	QSTART
			RETINJ
POSVEL	L*4	60	QSTART
			RETINJ
SPIRAL	L*4	64	TRAJ
			QPRINT
			QSTART
			RETINJ
VELOSS	L*4	68	TRAJ
			QSTART
			RETINJ
REGION	L*4	72	TAP
			CHECK
			DERIV
			FUNCT
			SOLAR
			QSTART
ERODE	L*4	76	TAP
			LOAD

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			CHECK
			DERIV
			EXTAB
			FUNCT
			PRIOR
			SOLAR
			TRAJI
			CDERIV
			OPRINT
			RKSTEP
			SPRINT
			TAPSET
FLAP	L*4	80	CHECK
			DERIV
			SOLAR
SPIN	L*4	84	SOLAR
TILT	L*4	88	CHECK
			SOLAR
HOUSE	L*4	92	SOLAR
TRACK	L*4	96	TAP
			SWINS
			FINISH
			OSTART
			SPRINT
PLANET	L*4	100	GETQ
			TRAJ
			RADAR
			TRAJI
			FINISH
			OPRINT
			OSTART
			SPRINT
OJEX	L*4	104	TAP
			TRAJ
			CHECK
			PRINT
			SOLAR
			STORE
			SWINS
			TRAJI
			CDERIV
			CORNER
			FINISH
			INTERP
			PRINTR
			OSTART
FIXTAU	L*4	108	TAP
			CHECK
			FUNCT
			TRAJI
			TAPSET

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
HEAT	L*4	112	TAP
			LOAD
			CHECK
			FUNCT
			SOLAR
			TRAJI
LOOSE	L*4	116	TRAJ
			TRAJI
			QPRINT
FIRST	L*4	120	TAP
			LOAD
			CDERIV
COAST	L*4	124	TAP
			LOAD
			STEP
			CHECK
			FUNCT
			SWSTD
			CDERIV
			INTERP
			SPRINT
QERODE	L*4	128	TAP
			DERIV
			PRIOR
			RKSTEP
PRZERO	L*4	132	GETQ
			TRAJ
			TRAJI
XLOAD	L*4	136	TRAJ
			QSTART
WIRL	L*4	140	TAP
			QSTART
PCURV	L*4	144	TAP
			LOAD
			CHECK
			DERIV
			FUNCT
			SOLAR
			TRAJI
			CDERIV
			QSTART
			SPRINT
MAXPOW	L*4	148	LOAD
			CHECK
			SOLAR
			TRAJI
			QSTART
EDGE	L*4	152	TAP
			CHECK
			SOLAR
			SPRINT

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
PLUS	L*4	156	TAP
			CHECK
			DERIV
			THANGD
JUMPED	L*4	160	TAP
			SWSTD
ALWAYS	L*4	164	GETD
			TRAJ
LDECL	L*4	168	GETRV
			PRINT
			TRAJI
BALLIS	L*4	172	TAP
			CHECK
QUIT	L*4	176	SWING
			TIKTOK
EXTRA	L*4	180	MORE
			FINISH
			SPRINT
OMORE	L*4	184	MORE
			SPRINT
TANDEM	L*4	188	MORE
			SWING
A1A	L*4	600	GETD
			SETUP
A1B	L*4	604	GETD
			TRAJ
			SETUP
A1C	L*4	608	GETD
			SETUP
A2A	L*4	612	GETD
			SETUP
A2B	L*4	616	GETD
			TRAJ
			SETUP
A2C	L*4	620	GETD
			SETUP
A3A	L*4	624	GETD
			SETUP
A3C	L*4	628	GETD
			SETUP
A4A	L*4	632	GETD
			SETUP
A4B	L*4	636	GETD
			SETUP
A4C	L*4	640	GETD
			SETUP
A5A	L*4	644	GETD
			SETUP
A5B	L*4	648	GETD
			SETUP
A5C	L*4	652	GETD

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			SETUP
A6A	L*4	656	GETQ
			SETUP
A6B	L*4	660	GETQ
			SETUP
A6C	L*4	664	GETQ
			SETUP
A7A	L*4	668	GETQ
			SETUP
A7B	L*4	672	GETQ
			SETUP
A7C	L*4	676	GETQ
			SETUP
A8A	L*4	680	GETQ
			SETUP
A8B	L*4	684	GETQ
			SETUP
A11A	L*4	688	GETQ
			SETUP
A11B	L*4	692	GETQ
			SETUP
A11C	L*4	696	GETQ
			TRAJ
			SETUP
A12A	L*4	700	GETQ
			SETUP
A12B	L*4	704	GETQ
			SETUP
A13A	L*4	708	GETQ
			TRAJ
			SETUP
A13B	L*4	712	GETQ
			SETUP
A14A	L*4	716	GETQ
			SETUP
A14B	L*4	720	GETQ
			SETUP
A14C	L*4	724	GETQ
			SETUP
A15A	L*4	728	GETQ
			SETUP
A15B	L*4	732	GETQ
			SETUP
A16A	L*4	736	GETQ
			SETUP
A16B	L*4	740	GETQ
			SETUP
A16C	L*4	744	GETQ
			SETUP
APHI	L*4	748	GETQ
			SETUP

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
A17A	L*4	828	GETQ
			SETUP
A17B	L*4	832	GETQ
			SETUP
A18A	L*4	836	GETQ
			TRAJ
			SETUP
A18B	L*4	840	GETQ
			SETUP
A19A	L*4	844	GETQ
			TRAJ
			SETUP
A19B	L*4	848	GETQ
			SETUP
A20A	L*4	852	GETQ
			TRAJ
			SETUP
A20B	L*4	856	GETQ
			SETUP
A41A	L*4	860	GETQ
			SETUP
A42A	L*4	864	GETQ
			SETUP
A43A	L*4	868	GETQ
			SETUP
A44A	L*4	872	GETQ
			SETUP
A44B	L*4	876	GETQ
			SETUP
A45A	L*4	880	GETQ
			SETUP
A45B	L*4	884	GETQ
			SETUP
A46A	L*4	888	GETQ
			SETUP
A46B	L*4	892	GETQ
			SETUP
A47A	L*4	896	GETQ
			SETUP
ABX	L*4	900	TRAJ
			QMASS
			PRINT
			TRAJI
			PRINTR
			QSTART
ABY	L*4	1180	GETQ
			QMASS
			PRINT
			SETUP
			PRINTR
			QSTART

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
A47B	L*4	1600	GETQ
			SETUP
A48A	L*4	1604	GETQ
			SETUP
A48B	L*4	1608	GETQ
			SETUP
A51A	L*4	1612	GETQ
			SETUP
A52A	L*4	1616	GETQ
			SETUP
A53A	L*4	1620	GETQ
			SETUP
A54A	L*4	1624	GETQ
			SETUP
A54B	L*4	1628	GETQ
			SETUP
A55A	L*4	1632	GETQ
			SETUP
A55B	L*4	1636	GETQ
			SETUP
A56A	L*4	1640	GETQ
			SETUP
A56B	L*4	1644	GETQ
			SETUP
A57A	L*4	1648	GETQ
			SETUP
A57B	L*4	1652	GETQ
			SETUP
A58A	L*4	1656	GETQ
			SETUP
A59B	L*4	1660	GETQ
			SETUP
A61A	L*4	1664	GETQ
			SETUP
A62A	L*4	1668	GETQ
			SETUP
A63A	L*4	1672	GETQ
			SETUP
A64A	L*4	1676	GETQ
			SETUP
A64B	L*4	1680	GETQ
			SETUP
A65A	L*4	1684	GETQ
			SETUP
A65B	L*4	1688	GETQ
			SETUP
A66A	L*4	1692	GETQ
			SETUP
A66B	L*4	1696	GETQ
			SETUP
A67A	L*4	1700	GETQ

COMMON LOGIC4 (CONTINUED)

VARIABLE	TYPE	ADDR	SUBROUTINE
			SETUP
A67B	L*4	1704	GETQ
			SETUP
A58A	L*4	1708	GETQ
			SETUP
A68B	L*4	1712	GETQ
			SETUP
A49A	L*4	1716	GETQ
			SETUP
A50A	L*4	1720	GETQ
			SETUP
A59A	L*4	1724	GETQ
			SETUP
A60A	L*4	1728	GETQ
			SETUP
A69A	L*4	1732	GETQ
			SETUP
A70A	L*4	1736	GETQ
			SETUP
A30A	L*4	1740	GETQ
			SETUP
A30B	L*4	1744	GETQ
			SETUP
A10A	L*4	1748	GETQ
			SETUP
A10B	L*4	1752	GETQ
			SETUP

COMMON VARIABLE CROSS REFERENCE TABLE

COMMON SOLSYS LENGTH 2240

VARIABLE	TYPE	ADDR	SUBROUTINE
GM	R*8	0	EFM
			TRAJ
			BEGIN
			SWING
			QSTART
RADIUS	R*8	560	TRAJ
			BEGIN
			SWING
APL	R*8	1120	MORE
			BEGIN
			SWING
			EFMPRT
			OPRINT
			SPRINT

B. HILTOP INPUT

1. NAMELIST. Inputs to HILTOP are given through the NAMELIST feature of the IBM Fortran IV programming language. The input NAMELIST is named MINPUT, and every input required or used in the program is declared by name in the list. The general form for assigning an input value to a quantity is, simply,

NAME = VALUE

where NAME is the name assigned to the variable and is included in the NAMELIST, and VALUE is a numerical or logical quantity consistent in form (i.e., logical, integer, or real) with NAME. Unless otherwise specified, all MINPUT names commencing with one of the letters I through N represent integers, whereas all names commencing with one of the letters A through H or O through Z are double precision floating point numbers. Each NAMELIST case must begin with the characters

& MINPUT

commencing in card colume 2 and followed by at least one blank, and end with the characters

&END

preceded by at least one blank. Card column 1 is ignored on all NAMELIST input cards. Multiple data assignments on a single card are permissible if separated by commas. Blanks in the variable field, VALUE, are taken as zeroes. A comma following the last VALUE on a card is optional on the IBM system. The order of the input data assignments is arbitrary; i.e., they need not be in the same order as listed in the NAMELIST. In fact, there is no requirement that any specific input parameter be represented in the input data set. If no value is included in the inputs for a particular parameter, the default value is used (see Default Values). For other details regarding the

NAMELIST feature, the reader is referred to the IBM System 360/Fortran IV Language manual. NAMELIST cases may be stacked back-to-back indefinitely.

2. Definitions of Input Parameters. Specific examples of the program inputs are given in the Sample Problems and Results section. Default-values of inputs are given in the next section.

The program inputs, in alphabetical order, are:

AAI	Desired final extra-ecliptic inclination, i. Related to AE, AR, and IOUT. [deg]
AE	Desired final extra-ecliptic eccentricity, e. Related to AAI, AR, and IOUT.
ALPHAA	Specific mass of solar arrays, α_a. [kg/kw]
ALPHAT	Specific mass of power conditioning and thruster subsystem, α_t. [kg/kw]
ALTITU	This input variable is associated with program logic which has not been kept up-to-date, specifically, logic pertaining to optimum departure of a NERVA-type rocket from Earth orbit. This variable should be ignored.
AN	Trajectory-integration exponent n in expression (39).
AR	Desired final extra-ecliptic perihelion distance, r_f. Related to AAI, AE, and IOUT. [AU]
ASOL	Array of five elements consisting of the solar power law coefficients a_i in expression (18). ASOL(1) > 0 tells the program to use the input coefficients rather than the internal coefficients. The coefficients are normalized internally, and the program executes the iterations to produce the required remarkable points of the power curve (which are printed).
BI	Efficiency coefficient b in expression (16). Related to DI and EI.

B1 B2 B3	Launch vehicle coefficients b_1, b_2, and b_3 in expression (2). Used only if MBOOST is negative. [kg, m/sec, kg]
CNI	Inclination to ecliptic of primary-target orbit. Input only when MOPT3 = 11. Related to ECI, OMI, SAI, SOI, TPI, EMUODD, and RADODD. [deg]
CNIX	Array of five elements, the first three of which may be currently used. Inclinations to ecliptic of intermediate-target orbits. Input CNIX(i) only when MOPTX(i) = 11. Related to ECIX, OMIX, SAIX, SOIX, TPIX, EMUODX, and RADODX. [deg]
CSTR	Structural factor, k_s, in expression (8).
CTANK	Propellant tankage factor, k_t, in expression (7).
CTRET	Retro tankage factor, k_{rt}, in expression (11).
DI	Efficiency coefficient d in expression (16). Related to BI and EI. [km/sec]
DMRETR	Retro engine mass, m_{rs}, in expression (11). [kg]
DPOW	Ratio of housekeeping power p_h to reference power p_{ref}. The power transmitted to the propulsion system is that generated by the arrays less housekeeping power which is constant along the trajectory. The power output of the arrays normal to the sun at 1 AU is $p_{ref} + p_h$. This option should not be invoked on missions during which large solar distances are encountered where the power developed is less than p_h. Erroneous results will be obtained.
ECI	Eccentricity of primary-target orbit. Must be less than unity. Input only when MOPT3 = 11. Related to CNI, OMI, SAI, SOI, TPI, EMUODD, and RADODD.
ECIX	Array of five elements, the first three of which may be currently used. Eccentricities of intermediate-target orbits. Input ECIX(i) only when MOPTX(i) = 11. Related to CNIX, OMIX, SAIX, SOIX, TPIX, EMUODX, and RADODX.
EI	Efficiency coefficient e in expression (16). Related to BI and DI.

EMUODD	Gravitational constant of primary-target. Input only when MOPT3 = 11. Related to ECI, CNI, OMI, SAI, SOI, TPI, and RADODD. [m^3/sec^2]
EMUODX	Array of five elements pertaining to the gravitational constants of intermediate-targets. These inputs must be ignored at present.
GAMMAX	Maximum permissible value of the power function γ when MODE = 5. At solar distances less than the value for which γ = GAMMAX, the solar arrays are assumed to be tilted such that γ is maintained at the limiting value.
GAP	Propulsion-corner proximity tolerance-interval, $\Delta\sigma$. See discussion in the section Avoiding Corners in the Propulsion-time Function. Whenever the thrust switch function σ grazes the zero-axis within the tolerance $\lvert\Delta\sigma\rvert$ on any trajectory, an internal counter is incremented, and the trajectory is considered to be in the neighborhood of a propulsion-time corner. Positive value of GAP causes forced-thrusting case to be inserted, negative value causes bypass to next case, whenever the internal counter reaches the related input variable NHUNG.
HOUR	Hour-of-day of reference date (e.g., 17.352D0). Related to MYEAR, MONTH, and MDAY.
IBAL	Ballistic option indicator. Setting IBAL $\neq 0$ invokes option 1 discussed in the section Ballistic Trajectory Option.
INTPR	Indicator which specifies print-length when the iteration in subroutine INTERP fails. Value of 0 causes shortprint and 1 causes detailed-print.
IOUT	Extra-ecliptic mission indicator. IOUT = 1 or 2 indicates that extra-ecliptic target conditions are desired, in which the iterator dependent variable triggers Y1(2) through Y6(2) are set equal to 1, and for which the input LAUNCH (which see) should probably be set to 1, and parameters related to LAUNCH also set appropriately. Ordinarily MOPT2 = 3. No retro stage may be employed. = 1 i, e, r_p specified; $f_n = 0$. = 2 i, e, a specified; f_n optimized. In the above, i = final extra-ecliptic inclination, e = final eccentricity, r_p = final perihelion distance, a = final semi- (continued on next page).

IOUT (cont.)	major axis, and f_n = true anomaly at the final time. Final Ω and ω are optimized in both cases. Related to AE, AR, and AAI.
IRK	Numerical integration option (currently not used).
IRL	Primer-origin-proximity step-size-control indicator. Value of zero causes the bypass of control, leaving the step-size Δu constant. See discussion in the section, Integration (Thrust).
IROT	A non-zero value of IROT causes the input ecliptic projection of the primer vector and its time derivative to be rotated about the z-axis through an angle equal to the difference in longitudes of the spacecraft between the last trajectory of the previous case (or zero if no previous case) and the first trajectory of the current case. This feature permits one to use the initial adjoint variables from a 2-dimensional trajectory as the initial-guess inputs for a 3-dimensional trajectory using the ephemeris option.
ISPIN	Spinner indicator. Not used at present.
ITF	Provides normal termination conditions for runs which require more machine time than is estimated. The value specifies the number of machine-time seconds (CPU and I/O) required to execute the summary trajectory after halting the iteration-sequence. [sec] Does not apply if subroutine REMTIM is dummied.
ITPRNT	Indicator for special print from MINMX3 iterator. Non-zero value invokes print.
JPP	Jettison indicator j_{ps} for electric propulsion system prior to primary-target retro-maneuver, as used in expression (9). = 0 Propulsion system not jettisoned = 1 Propulsion system jettisoned prior to retro maneuver.
JPRINT	Unit 11 printout-length indicator. A value of zero causes the iterator independent and dependent variables to be output only for each summary-trajectory; a value of one causes the same output additionally at each iteration of an iteration sequence.

JT Jettison indicator j_t for electric propulsion tankage prior to primary-target retro-maneuver, as used in expression (9).

= 0 Tankage not jettisoned

= 1 Tankage jettisoned prior to retro-maneuver.

KPART Option for automatically selecting improved independent parameter perturbations for generating the iterator's partial derivative matrix. The option is invoked by setting KPART = N (N > 0), where N is the maximum number of allowed steps, as discussed in the section, Perturbation Step Size Selector. KPART must be set back to zero if not desired on subsequent cases.

LAUNCH Launch mode selector, pertaining to the optimization of the departure asymptote declination, invoked by LAUNCH = 1. Related to X10, Y10, X17, and Y17.

LOADX Intermediate-target initial-guess feature. Should be used with NSET(5) = 1, and then set to zero on the subsequent case. A non-zero value of LOADX will invoke this feature, whereby the primer Λ and its derivative $\dot{\Lambda}$ will be loaded into the iterator independent-variable arrays at each intermediate-target provided that the trigger of the independent variable is on. The sole purpose of this capability is merely to generate an initial-guess for a multiple-target mission, where the values loaded into the iterator arrays represent continuous Λ and $\dot{\Lambda}$ at each target.

MAXHAM Maximum number of times that the program will print the warning message BAD HAMILTONIAN on any given computer run.

MBOOST Launch vehicle selector.

= 0 ATLAS (SLV3X)/CENTAUR
1 TITAN III C
2 TITAN III C (1207)
3 TITAN III X/CENTAUR
4 TITAN III X (1207)
5 TITAN III X (1207)/CENTAUR
6 SATURN IB/LM
7 SATURN IB/CENTAUR
8 SATURN IC/SIVB/CENTAUR
9 TITAN III X (1205)/CENTAUR
10 TITAN III B (CORE)/CENTAUR
11 TITAN III D (1205)/CENTAUR

(continued on next page).

MBOOST (cont)	=12	DELTA
	13	TITAN III D
	14	TITAN III D (1205)/CENTAUR/TE364 (2250)
	15	TITAN III E/CENTAUR
	16	SHUTTLE/TRANSTAGE
	17	SHUTTLE/DELTA
	18	SHUTTLE/AGENA
	19	SHUTTLE/CENTAUR
	20	SHUTTLE/CENTAUR/BURNER II (2300)
	NEG	Use input booster coefficients B1, B2, and B3.

MDAY — Day-of-month of reference date (e.g., 26). Related to MYEAR, MONTH and HOUR.

MODE — Power variation option selector. The value of MODE is equal to the option-number of the power-curve, discussed in the section, Electric Propulsion System (which see). Possibly related to ASOL and GAMMAX. MODE = 1 has been eliminated.

MONTH — Month-of-year of reference date (e.g., 8). Related to MYEAR, MDAY, and HOUR.

MOPT — Ballistic option indicator. Using MOPT invokes option 2, discussed in the section, Ballistic Trajectory Option, as follows:

= 0 No action (use input Λ_o, $\mathring{\Lambda}_o$, and $v_{\infty o}$).

= 1 Generate ballistic solution with flyby end conditions.

= 2 Generate ballistic solution with orbiter end conditions.

Related to REVS.

MOPTX — Array of five elements, the first three of which may be currently used. This array specifies the target-number, or planet-number, of the successive intermediate-targets, and a value of zero indicates absence of the intermediate-target. A zero-entry must not precede a non-zero entry. Planet selection is the same as for MOPT2. MOPTX(1) pertains to iterator parameters X41-X50 and Y41-Y50; MOPTX(2) pertains to X51-X60 and Y51-Y60; and MOPTX(3) pertains to X61-X70 and Y61-Y70. Times at the targets are X48, X58, and X68. Not to be used unless MOPT2 $\neq$ 0.

MOPT2 Launch planet number and ephemeris-option indicator.

= 0 Analytical planetary ephemeris is not used.

≠ 0 Analytical planetary ephemeris is used and the specific launch planet is selected as follows:

= 1	Mercury	= 27	Hebe
2	Venus	28	Iris
3	Earth	29	Flora
4	Mars	30	Achilles
5	Jupiter	31	Amor
6	Saturn	32	Hidalgo
7	Uranus	33	Alinda
8	Neptune	34	Grigg-Skjellerup (1977)*
9	Pluto	35	Kopff
10	Ceres	36	Grigg-Skjellerup (1982)*
11	Input Target **	37	Ganymed
12	D'Arrest (1982)*	38	Ivar
13	Encke (1980)*	39	Beira
14	Icarus (1987)*	40	Kepler
15	Eros	41	Giacobini-Zinner (1985)*
16	Geographos (1983)*	42	Borrelly (1987)*
17	Encke (1977)*	43	Tempel II (1988)*
18	Encke (1984)*	44	Tempel II (1983)*
19	Encke (1987)*	45	Tuttle-Giacobini-Kresak
20	Halley	46	Schaumasse
21	Betulia	47	Honda-Mrkos-Pajdusakova
22	Toro (1983)*	48	Giacobini-Zinner (1979)*
23	Pallas	49	Icarus (1987)*
24	Juno	50	Toro (1987)*
25	Vesta	51	Geographos (1987)*
26	Astraea		

MOPT3 Planet number of primary target. Planet selection is the same as for MOPT2. If ephemeris is not used, MOPT3 is used only for retro-stage mass computations.

MOPT4 Array of ten elements, specifying up to ten post-swingby targets. Planet selection is the same as for MOPT2, and a value of zero indicates the absence of a post-swingby target. A negative value in MOPT4(1) selects <u>multiple</u> ballistic swingbys, rather than a set of single swingbys in which case also set MAXHAM = 0. Negative values (in absolute value) produce planet selection the same as for MOPT2. When MOPT4(1) < 0, the remaining elements of MOPT4(i)

(continued on next page)

*Year-value indicates apparition for which internal orbital elements are most accurate.

**Input corresponding orbit elements (see CNI, CNIX). None are available for the launch planet.

MOPT4 (cont) — may be positive or negative. See the section, Swingby Continuation Analysis for details and Sample Case H for an example-case. Should be used only for primary-target flyby missions. Related to T2, MSWING, NSWING and XSWING.

MPOW — Flag used in conjunction with the solar array degradation option. Value of zero results in the optimum orientation of the arrays relative to the sun line. A non-zero value forces the arrays to an orientation yielding the maximum power achievable at that instant. Related to TPOWER.

MPRINT — Indicator for printing the summary-trajectory (final trajectory of a case) as a function of time or for invoking extra printout.

- = 0 Small-size block print at thrust switch points only (SWITCH POINT SUMMARY page).
- = 1 Same as = 0, except expands to become a standard print-block of parameters for each computed point along the trajectory, including the trajectory extension controlled by the input variable TGO.
- = 2 Same as = 0, except each block contains extra lines consisting of target-relative coordinates and target magnitudes.
- = 3 Combination of = 1 and = 2.

MPUNCH — Punched-card and trajectory-tape generation control.

- = 0 No special output.
- 1 Punch final values of independent parameters.
- 2 In addition, punch selected mission analysis parameters used for graphic documentation or other purposes.
- < 0 and > - 100 Punch trajectory output used with the ASTEA program. The absolute value of MPUNCH determines the frequency of trajectory points output, e.g., -3 would result in the punching of every third integration point.
- ≤ - 101 Trajectory tape output used with the ASTEA program. The absolute value less 100 determines the frequency of trajectory points output. Related to NTAPE.

MREAD — Card input option (iterator independent variables)

= 0 No special cards input.
(Continued on next page).

MREAD (cont)

= 1 The independent variables generated by a previous run by the MPUNCH = 1 or 2 option are input following the NAMELIST case, as discussed in the section, Program Output.

MSWING

Array of ten elements, used only when running multiple-target ballistic swingbys, such that MSWING(i) corresponds to MOPT4(i) and selects the type of swingby maneuver desired at the respective swingby target. Used only if MOPT4(1) < 0. The shooting method (MINMX3 iterator) is used, and values of -1, -2, or -3 correspond to a swingby passage distance initial guess of $r_p = \infty$ (i.e., continuous heliocentric velocity). Each element MSWING(i) may have any of the following values:

= - 1 Go* directly for unpowered swingby; if and only if it fails, go for powered swingby having flight time T2(i) = initial guess.

= - 2 Go directly for powered swingby only, having T2(i) = flight time of post-swingby leg.

= - 3 Go directly for unpowered swingby; then, whether it succeeds or not, go for powered swingby having T2(i) = flight time.

= - 4 Go directly for unpowered swingby, but using initial velocity guess loaded into XSWING(j, i), j = 1,2,3, similar to MSWING(i) = - 1.

= - 5 Same as = - 2, except use initial guess as in = - 4.

*"Go for" means "attempt to obtain (solution)".
Related to MOPT4, T2, XSWING, and NSWING.

MTMASS

Mission-type selector pertaining to the primary target.

= 0 Flyby mission.

1 Orbiter (high-thrust retro-maneuver without velocity loss).

2 Orbiter (high-thrust retro-maneuver with velocity loss).

3 Specified arrival excess speed $v_{\infty n}$.

If $v_{\infty n} = 0$, rendezvous mission

If $v_{\infty n} > 0$, controlled flyby mission

No retro-maneuver in either case.

4 Orbiter (Electric propulsion system performs spiral maneuver. Arrival excess speed $v_{\infty n}$ must be specified as zero).

(continued on next page)

MTMASS (cont)	Other parameters which may be related to MTMASS are DMRETR, CTRET, RPER, RAP, THRET, SPIRET, JPP, and JT.
MUPDAT	Flag indicating whether iterator independent variables at end of one case are to be updated for use as first guesses of next case. = 0 Do not update independent parameters. 1 Update independent parameters for next case to be those obtained at end of iteration on the current case.
MYEAR	Year of reference date (e.g., 1982). Related to MONTH, MDAY, and HOUR.
NDIST	Identification number of celestial body to be used as the reference for the communication distance and angle measurement printed in the Extremum Point Summary Table. Identification code is the same as for MOPT2.
NHUNG	Maximum number of propulsion-corner-proximity occurrences allowed in a given iteration-sequence. Related to GAP.
NORMAL	Automatic adjoint-variable scaling. = 0 No action. 1 All Λ and $\dot{\Lambda}$ are scaled such that $\lambda_{\nu o}$ becomes unity.
NPERF	Identification number of end condition that is to be used as the performance index when employing the direct parameter optimization feature (Improve Mode). The identification code is the same as the i in the Yi end condition array.
NPRINT	Print selection flag. Permits selection of amount of printout desired on each case. = 0 Print only the case summary. 1 Print switching point summary of final trajectory. 2 Print MINPUT and case setup. 4 Print trajectory summary on each iteration. 8 Print partial derivative matrix each iteration. Combinations of options obtained by summing options desired. If NPRINT > 15, printout consistent with NPRINT = 0 is obtained. (continued on next page).

NPRINT (cont)

If the sign of NPRINT is reversed to negative, the iterator independent and dependent variables additionally are printed for every trajectory which HILTOP generates (including neighboring trajectories).

NSET

Iteration-sequence control array.

NSET(1) Not used for input.

NSET(2) Not used for input.

NSET(3) Maximum number of iterations permitted in attempting to satisfy constraints in satisfy mode. If zero, no upper limit imposed.

NSET(4) Flag indicating whether constraints are to be satisfied prior to entering improve mode.

= 0 Satisfy constraints first.

1 Proceed immediately to improve mode.

NSET(5) Maximum number of iterations permitted after entering improve mode. Setting NSET(5) = 1 causes iterator to be bypassed and computes single trajectory to obtain printout.

NSWING

Swingby continuation analysis option indicator. NSWING must be negative and has the same definition as MSWING (which see); NSWING must be used when MOPT4(1) > 0, and <u>may</u> be used when MOPT4(1) < 0. If MOPT4(1) < 0 and MSWING(i) = 0, then MSWING(i) will be set to the value of NSWING. Related to MSWING, MOPT4 and T2.

NSWPAR

Iterator independent-variable perturbation-increment control.

= 0 No action.

1 Allows the iterator to vary a given independent-variable perturbation Δx whenever a neighboring trajectory is detected which has a different number of thrust switch points than the associated nominal trajectory. Δx is varied until the same number of switch points is achieved.

NTAPE

Specifies the unit-number for the ASTEA trajectory tape. Pertains to when MPUNCH ≤ -101.

OMI	Ascending node angle (with respect to vernal equinox) of primary-target orbit. Input only when MOPT3 = 11. Related to CNI, ECI, SAI, SOI, TPI, EMUODD, and RADODD. [deg]
OMIX	Array of five elements, the first three of which may be currently used. Ascending node angles of intermediate-target orbits. Input OMIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, SAIX, SOIX, TPIX, EMUODX, and RADODX. [deg]
POWFIX	Launch-vehicle-independent (i.e., no launch vehicle) trajectory option in which the value of POWFIX is the spacecraft's reference power. [kw]
PSIGN	Flag defining the sense of the launch hyperbolic excess velocity relative to the initial primer vector. A value of +1. results in the assignment of the geocentric right ascension of the excess velocity equal to that of the initial primer vector. A value of -1. causes the geocentric right ascension of the excess velocity to be 180 degrees from that of the initial primer.
RADODD	Radius of primary target. Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SAI, SOI, TPI, and EMUODD. [meters]
RADODX	Array of five elements pertaining to the radii of intermediate targets. These inputs are not used at present.
RAP	Apoapse distance of capture orbit about primary target. [planet radii]
REVS	Number of complete revolutions of the ballistic trajectory generated when the associated input MOPT is used. Must be a positive whole number.
RPER	Periapse distance of capture orbit about primary target. [planet radii]
SAI	Semi-major axis of primary-target orbit (must be positive). Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SOI, TPI, EMUODD, and RADODD. [AU]
SAIX	Array of five elements, the first three of which may be currently used. Semi-major axes of intermediate-target orbits (must be positive). Input SAIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, OMIX, SOIX, TPIX, EMUODX, and RADODX. [AU]

SOI — Argument of perihelion of primary-target orbit. Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SAI, TPI, EMUODD, and RADODD. [deg]

SOIX — Array of five elements, the first three of which may be currently used. Arguments of perihelion of intermediate-target orbits. Input SOIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, OMIX, SAIX, TPIX, EMUODX, and RADODX. [deg]

SPIRET — Retro-stage specific impulse (pertaining to the retro-maneuver at the primary target). [sec]

STATE — Array of six elements containing the Cartesian position and velocity components of the primary target. Use only when MOPT2 = 0 and the trigger settings of Y1(2) through Y6(2) are 0 or 1. [AU, AU/tau] (tau = 58.132440991 days)

STEP1 — Thrust-phase computation step size, Δu. Related to AN.

STEP2 — Coast-phase computation step size, $\Delta \beta$.

TCOAST — Array of twenty elements, consisting of the durations of the coast phases corresponding to the coast-phase start-times input in the associated array TOFF. [days]

TDV — Time of occurrence of an impulsive deep space burn, in days from the start of the trajectory, which may be used only if the entire trajectory is ballistic (i.e., electric propulsion is not permitted with this option, nor is a third intermediate target). Iterator independent variables X64, X65, and X66 must be turned on, as these are used as the ΔV vector components of the deep space burn in EMOS. Also, set MAXHAM = 0. The following special feature is available regarding a first intermediate-target. If 1.D5 < TDV < 2.D5, then the burn occurs (TDV - 1.D5) days after passage of that target; if TDV > 2.D5, the burn occurs (TDV - 2.D5) days before passage of that target. [days]

TGO — Ballistic trajectory-extension print option. When zero, no action. When positive, TGO = the number of days that the trajectory is to extend ballistically beyond the primary-target when no swingby-continuation is requested, and ballistically beyond the (last) post-swingby target when swingby-continuation is requested (in addition to the post-swingby trajectory segment itself). Any negative value will invoke printout of only the post-swingby trajectory segment or segments when swingby-continuation is requested. Applies also to trajectories with multiple swingbys. [days]

THRET — Retro-stage thrust, f_r, used only when MTMASS = 2. [lbs]

TOFF — Array of twenty elements, consisting of the times, in days from the start of the trajectory, at which imposed coast phases are to begin. Times must be in ascending order. Related to TCOAST. [days]

TPI — Time from reference date (MYEAR, etc.) to perihelion passage, for the primary target. Input only when MOPT3 = 11. Related to CNI, ECI, OMI, SAI, SOI, EMUODD, and RADODD. [days]

TPIX — Array of five elements, the first three of which may be currently used. Times from reference date (MYEAR, etc.) to perihelion passages, for the intermediate targets. Input TPIX(i) only when MOPTX(i) = 11. Related to CNIX, ECIX, OMIX, SAIX, SOIX, EMUODX, and RADODX. [days]

TPOWER — Solar-cell degradation characteristic-time; nuclear electric propulsion radioactive-decay characteristic-time. Related to MPOW. [days]

TSCALE — Iterator dependent-variable tolerance-interval scaling factor; scales all tolerances multiplicatively by the amount TSCALE.

T2 — Array of ten elements consisting of initial estimates of swingby-continuation trajectory-segment flight-times, i.e., T2(i) corresponds to MOPT4(i). [days]

XANG1 — Latitude of the launch site. Used only if LAUNCH is non-zero. Related to XANG2. [deg]

XANG2 — Maximum parking orbit inclination permitted by range safety considerations. Used only if LAUNCH is non-zero. Related to XANG1. [deg]

XSWING — Array of velocity vectors consisting of initial velocity guesses of a given post-swingby trajectory segment. Used only when either NSWING or MSWING has a value of -4 or -5. See especially the description of MSWING = -4. Velocity consists of exactly the same values as found in the V1, V2, V3 locations of the trajectory block print (first block). Related to MSWING, NSWING, MOPT4, and T2. [AU/tau]

X0 Array of seven elements, the first six of which contain the Cartesian position and velocity components of the launch planet. The seventh element is not used for input. Used only when MOPT2 = 0. [AU, AU/tau]

The following describes the iterator independent and dependent variable arrays of the boundary value problem. Input pertaining to the individual independent parameters is contained in the arrays X1 through X70. The independent-parameter arrays have five elements for each variable, as follows (where i = 1, 2, 3, ..., 70):

Xi(1) Input value of parameter. Must be input regardless of trigger setting. If trigger is on (i.e., Xi(2) = 1), input value is used as initial guess of independent parameter and is varied at each subsequent iteration. If trigger is off, the parameter is not used as an independent parameter and is not changed.

Xi(2) Trigger indicating whether parameter is to be an independent parameter in boundary value problem.

Xi(2) = 0 Not an independent parameter. (Trigger is "off").

1 Use as independent parameter. (Trigger is "on").

Xi(3) Maximum change to parameter permitted in a single iteration. Should be a positive quantity. Used only if trigger is on. Units are same as that of the parameter.

Xi(4) Perturbation increment used to compute partial derivatives by finite differences. Used only if trigger is on. Units are same as that of the parameter.

Xi(5) Weighting factor. Should be a positive quantity. A value of 1. is generally recommended. The larger the weighting factor, the more the parameter is inhibited from varying. Used only if trigger is on.

The independent variables are as follows:

X1	$\Lambda_o(1)$	
X2	$\Lambda_o(2)$	Initial primer vector.
X3	$\Lambda_o(3)$	
X4	$\dot{\Lambda}_o(1)$	
X5	$\dot{\Lambda}_o(2)$	Initial primer derivative.
X6	$\dot{\Lambda}_o(3)$	
X7	$\lambda_{\nu o}$	Initial mass-ratio adjoint-variable.
X8	λ_τ	Propulsion-time adjoint-variable.
X9		Not used.
X10	δ	Geocentric declination of launch hyperbolic excess velocity. [deg]

There is no conversion from input to internal units for any of the adjoint variables.

X11	Reference thrust acceleration, g. [m/sec^2]
X12	Electric propulsion system jet exhaust speed, c. [m/sec]
X13	Launch hyperbolic excess speed, $v_{\infty o}$. [m/sec]
X14	Hyperbolic excess speed at primary target, $v_{\infty n}$. [m/sec]
X15	Initial time, t_o, measured from the reference date (MYEAR, etc.). [days]
X16	Time at the primary target, t_n, measured from the reference date (MYEAR, etc.). [days]
X17	Launch parking orbit inclination, i. Used only if LAUNCH = 1. Optimized internally by the program if both X17 and Y17 triggers are off. [deg]

X18	$\dot{x}_o$	Initial spacecraft heliocentric velocity. Not required unless one of the three triggers is on. [AU/tau] (tau = 58.132440991 days)
X19	$\dot{y}_o$	
X20	$\dot{z}_o$	
X21		Constant thrust cone-angle, ϕ. Non-zero value invokes the constant-ϕ constraint. $0 < \phi \leq 180^o$. Zero-value implies that ϕ is optimized along the trajectory (variable ϕ). [deg]

X22 through X29 are currently not used (although some locations following X21 are reserved for additional constant thrust cone-angles).

X30	λ_s	Degradation-time adjoint-variable.

X31 through X40 are currently not used. X41 through X50 pertain to the first intermediate target, X51 through X60 pertain to the second intermediate target, and X61 through X70 pertain to the third intermediate target. The corresponding intermediate-target parameters are ignored if the intermediate target is absent. Subscripts 1, 2, and 3 pertain to the first, second, and third intermediate targets, respectively.

X41	$\Lambda_1(1)$	Primer vector (at start of trajectory segment)
X42	$\Lambda_1(2)$	
X43	$\Lambda_1(3)$	
X44	$\dot{\Lambda}_1(1)$	Primer derivative (at start of trajectory segment)
X45	$\dot{\Lambda}_1(2)$	
X46	$\dot{\Lambda}_1(3)$	
X47		Encounter speed at first intermediate target, $v_{\infty 1}$. [m/sec]

X48	Time at the first intermediate target, t_1, measured from the reference date (MYEAR, etc.). [days]
X49	Sample-mass factor, $k_{samp\ 1}$, for sample-retrieval at first intermediate target.
X50	Drop-mass factor, $k_{drop\ 1}$, for instrument-package dropoff at first intermediate target.

The independent variables X51 through X60 and X61 through X70 are identical to X41 through X50 except that they pertain to the second and third intermediate targets, respectively. A third intermediate target may not be present when simulating ballistic missions having a deep space burn (See TDV), in which case X64, X65, and X66 are used as follows:

$$\left.\begin{array}{ll} X64 & \Delta\dot{x} \\ X65 & \Delta\dot{y} \\ X66 & \Delta\dot{z} \end{array}\right\} \text{Deep-space velocity-increment. [AU/tau]}$$

Inputs pertaining to the individual dependent parameters are contained in the arrays Y1 through Y70. The dependent-parameter arrays have three elements for each variable, as follows (where i = 1, 2, 3, ..., 70):

Yi(1)	Desired value of the dependent parameter.
Yi(2)	Trigger. If off (i.e., equal to zero), the parameter is ignored and is not considered a dependent parameter. Then the other two inputs pertaining to the parameter need not be input. If trigger is on, (i.e., not equal to zero), the parameter is considered to be a dependent parameter or constraint. Certain of the parameters may have up to three non-zero trigger settings. These will be discussed individually below.
Yi(3)	Tolerance of desired value (full interval width).

It should be noted that the transversality conditions, which comprise some of the parameters, are developed under the assumption that all constraints are of the point constraint type. Therefore, the satisfy-mode is sufficient in solving any optimization problems for which a complete set of transversality conditions is available.

The dependent-parameter arrays are as given below. $T(x)$ represents "the transversality condition associated with x" and the function $T(x)$ will have different values depending upon the constraints imposed on the problem. See NOMENCLATURE for definition of symbols and subscripts.

	Trigger 1			Trigger 2		Trigger 3	
Y1	Δx_n [AU]	;	a[AU]	Solar distance* [AU]		$T(\sigma)$	
Y2	Δy_n [AU]	;	e	$T(\theta_t)$*		$T(\theta_t)$	
Y3	Δz_n [AU]	;	i[deg]			$T(t_n)$	
Y4	$\Delta \dot{x}_n$ [AU/tau]	;	$T(\Omega)$	$T(\dot{x}_n)$		$T(\xi)$	NERVA
Y5	$\Delta \dot{y}_n$ [AU/tau]	;	$T(\omega)$	$T(\dot{y}_n)$	optimal flyby	$v_{\infty o}$	
Y6	$\Delta \dot{z}_n$ [AU/tau]	;	$T(f)$	$T(\dot{z}_n)$		$T(\lambda)$	

*Applicable only for two-dimensional motion in the xy plane. Also requires that MOPT2 = 0.

Under Trigger 1 above, the first set of conditions applies to ordinary targeting conditions for position and velocity, and also to extra-ecliptic conditions to be satisfied when IOUT = 1; the second set of conditions applies to extra-ecliptic missions when IOUT = 2. $T(\Omega)$, $T(\omega)$, and $T(f)$ are symbols for the transversality conditions yielding optimum final node angle, argument of perihelion, and true anomaly, respectively.

	Trigger 1	Trigger 2	Trigger 3
Y7	ν_n	$\lambda_{\nu n}$	m_{net} [kg]
Y8	$T(\tau)$	τ [days]	
Y9	Currently not used.		
Y10	$T(\delta)$	δ [deg]	Used only if LAUNCH $\neq 0$.
Y11	$T(g)$	g [m/sec^2]	p_{ref} [kw]
Y12	$T(c)$	c [m/sec]	
Y13	$T(v_{\infty o})$	$v_{\infty o}$ [m/sec]	
Y14	$T(v_{\infty n})$	$v_{\infty n}$ [m/sec]	extra-ecliptic inclination [deg]
Y15	$T(t_o)$	t_o [days]	
Y16	$T(t_n)$	t_n [days]	$t_n - t_o$ [days]*

*Time transversality with flight time fixed is assigned to Y15 under trigger 1.

Y17	$T(i)$	i [deg], where i = parking orbit inclination.	Used only if LAUNCH $\neq 0$.
Y18	$T(\dot{x}_o)$	$\dot{x}_o$ [AU/tau]	
Y19	$T(\dot{y}_o)$	$\dot{y}_o$ [AU/tau]	
Y20	$T(\dot{z}_o)$	$\dot{z}_o$ [AU/tau]	
Y21	$T(\phi)$	ϕ [deg] for ϕ = constant with time.	

Y22 through Y29 are currently not used.

Y30	$T(s)$	s [days]	(Degradation time)

Y31 through Y40 are currently not used. Y41 through Y50 pertain to the first intermediate target.

Y41	Δx_1 [AU]		

	Trigger 1	Trigger 2	
Y42	Δy_1 [AU]		
Y43	Δz_1 [AU]		
Y44	$\Delta \dot{x}_1$ [AU/tau]	$T(\dot{x}_1)$	optimal flyby
Y45	$\Delta \dot{y}_1$ [AU/tau]	$T(\dot{y}_1)$	
Y46	$\Delta \dot{z}_1$ [AU/tau]	$T(\dot{z}_1)$	
Y47		$v_{\infty 1}$ [m/sec]	
Y48	$T(t_1)$	t_1 [days]	
Y49	$m_{samp\,1}$ [kg]		
Y50	$m_{drop\,1}$ [kg]		

Y51 through Y60 and Y61 through Y70 are identical to Y41 through Y50 except that they pertain to the second and third intermediate targets, respectively.

3. Default Values of Input Parameters. The following is a complete, alphabetical list of the default values of program input quantities having non-zero default values, except for the iterator arrays. All other inputs are zeroed. The default values of the iterator arrays Xi(1), Xi(2), Yi(1), and Yi(2), for i = 1,2,3,...,70, are zero, and the default values of Xi(3) through Xi(5) and Yi(3) for the same range of i are listed in the listing of program inputs of Sample Case H.

ALPHAA	15.	IRK	1
ALPHAT	15.	IRL	1
AN	1.5	ITF	3
AR	1.	MAXHAM	5
BI	.76	MDAY	1
CTANK	.03	MODE	4
CTRET	1/9	MONTH	1
DI	13.	MOPT3	10
GAMMAX	1.	MUPDAT	1
GAP	.0001	MYEAR	1975
HOUR	12.	NDIST	3

NHUNG	25	STATE(1)	1.
NPRINT	7	STATE(5)	1.
NSET(3)	300	STEP1	.03125
NSET(5)	300	STEP2	.125
NSWPAR	1	TDV	-1.
NTAPE	17	TGO	-1.
POWFIX	-1.	THRET	400.
PSIGN	1.	TOFF	20*-1.
RADODD	1.	TPOWER	10.**30
RAP	38.	TSCALE	1.
RPER	2.	T2(i)	50*i
SAI	1.	X0(1)	1.
SPIRET	300.	X0(5)	1.0000015

C. PROGRAM OUTPUT

Program output under normal termination conditions provides a listing of the program inputs, a description of the iterator independent and dependent variables, the iteration history, the thrust switching history (which optionally expands to become the trajectory block print), an iterator summary-page describing the results of the iteration, the table of extrema of selected trajectory functions, the mission schedule giving calendar dates and target positions and velocities, and the performance summary page describing the spacecraft masses. These output components are best understood by perusing the various sample cases which are included in this document.

The listing of the program inputs consists of a listing of the iterator independent and dependent variable arrays, followed by a presentation of the remaining program inputs, which is alphabetical except that floating-point quantities precede integer quantities.

The page describing the iterator independent and dependent variables contains only those X and Y parameters (from the listing of program inputs) having non-zero trigger values, as these are the parameters relevant to the boundary value problem to be solved. The index of each independent and dependent variable is given, together with the value of each independent variable, the desired value of each dependent variable, the independent-variable iteration-step limits and neighboring-trajectory perturbation-increments, the dependent-variable acceptability-tolerances, and the iterator weights.

The iteration history consists of a summary-print of the iterator independent and dependent variables at each iteration-step, and also the thrust switching times, spacecraft masses, and propulsion system parameters. Depending on the value of the input variable NPRINT, the iterator partial derivative matrix $-\partial y_i/\partial x_j$ may be printed, and also a summary-print of every trajectory which the program generates, including the neighboring trajectories, may be obtained. In the partial

derivative matrix, y_i are the relevant dependent parameters, x_j are the relevant independent parameters, and i is the row index.

The thrust switching history expands to become the trajectory block-print according to the value assigned to the input variable MPRINT. The individual components of the block-print are described in the section, Auxiliary Computations. The block-print occurs at each compute-step, which generally corresponds to fixed increments in the trajectory independent variable, u on thrust arcs and β on coast arcs. This is not available as the iteration proceeds but only on the final, summary-trajectory of each case.

The iterator summary page displays all of the iterator independent variables (at the end of the current iteration), since many of them affect the trajectory computations even when they are held fixed. Also displayed is the "switch-count history", which is a listing of the total number of thrust switching points on the nominal trajectory of each iteration-step, and the number of both thrust-phase and coast-phase computation steps for the current summary-trajectory, which is the final trajectory at the end of the iteration-sequence for the given case.

The entries in the table of extrema of selected trajectory functions are described in the section, Auxiliary Computations. The mission schedule gives the position, velocity, solar distance, and ecliptic latitude and longitude of the spacecraft and each target at the target intercept or rendezvous time, and also the two-body transfer angle between the launch planet and each target.

The performance summary page includes a mission-type and launch vehicle description, electric propulsion system structural parameters and mass summary, extreme trajectory and performance conditions, launch and primary-target hyperbolic excess speeds and, if applicable, the high thrust retro maneuver and capture orbit summary pertaining to the primary target.

A print option is available which allows the extension of the summary-trajectory ballistically beyond its normal endpoint, which is useful for determining where the spacecraft goes after the primary mission objectives have been accomplished. This print option is controlled by the program input quantity TGO, and consists of the trajectory block-print, extremum table of selected functions, and an additional mission schedule entry. This print option is displayed automatically whenever the primary-target swingby-continuation-analysis is requested.

HILTOP optionally provides punched-card output for each case under normal program termination conditions. When the program input variable MPUNCH = 1, the punched-card output consists of seven cards for each case, containing all seventy of the iterator independent variables consecutively, each card containing ten independent variables in A8 format, 10A8. It is these seven cards which may be used to initiate a trajectory on a subsequent run, by using the program input variable MREAD = 1. When the program input variable MPUNCH = 2, five additional cards are punched for each case, and these cards contain the pertinent information which summarize a converged, optimal trajectory. No cards are punched for a given case if a trajectory or iterator error condition exists for that case, including convergence failure or obtaining maximum allowable iterations. The contents of the five summary cards (cards 8 through 12), having units identical to the program input units, are as follows:

Card 8		Format
power function indicator, MODE		I2
numerical integration indicator, IRK		I1
launch vehicle indicator, MBOOST		I2
ballistic solution indicator, MOPT		I1
day of month, MDAY		I2
month of year, MONTH	reference date	I2
years since 1900, MYEAR - 1900		I2

Card 8 (cont)	Format
Λ, $\mathring{\Lambda}$ rotation indicator, IROT	I1
retro maneuver propulsion system jettison indicator, JPP	I1
retro maneuver tankage jettison indicator, JT	I1
launch planet indicator, MOPT2	I2
primary target indicator, MOPT3	I2
mission-type indicator, MTMASS	I2
ballistic solution indicator, IBAL	I1
blank	I1
launch mode indicator, LAUNCH	I1
star-sighting indicator, ISTAR	I2
spacer	50x
case number	I2
card identifier	I2

Card 9	Format
specific mass, $\alpha = \alpha_t + (1 + \Delta p)\,\alpha_a$	A4
tankage factor, k_t	A4
structure factor, k_s	A4
retro engine mass, m_{rs}	A4
retro tankage factor, k_{rt}	A4
primary-target orbit periapse distance, r_p	A4
primary-target orbit apoapse distance, r_a	A4
retro stage thrust magnitude, f_r	A4
retro stage specific impulse	A4
hour of the day (reference date)	A4
extra-ecliptic final inclination	A4
efficiency coefficient, b	A4
efficiency coefficient, d	A4

Card 9 (cont)	Format
efficiency coefficient, e	A4
launch vehicle coefficient, b_1	A4
launch vehicle coefficient, b_2	A4
launch vehicle coefficient, b_3	A4
extra-ecliptic perihelion distance	A4
extra-ecliptic final eccentricity	A4
case number	I2
card identifier	I2

Card 10	Format
input primary-target position and velocity	6A4
input initial state and mass ratio	7A4
reference power in no-launch-vehicle mode, p_{ref}	A4
thrust-phase computation step size, Δu	A4
coast-phase computation step size, $\Delta \beta$	A4
unused location	A4
input primary-target gravity constant, μ_t	A4
input primary-target radius	A4
case number	I2
card identifier	I2

Card 11	Format
input primary-target semimajor axis	A4
input primary-target eccentricity	A4
input primary-target inclination	A4
input primary-target ascending node	A4
input primary-target argument of perihelion	A4
input primary-target perihelion time	A4
exponent in step-size law, n	A4

Card 11 (cont)	Format
launch-site latitude, L	A4
range safety limit, i_{max}	A4
launch asymptote declination, δ	A4
launch parking orbit inclination, i	A4
primary-target communication distance, r_c	A4
primary-target communication angle, α_c	A4
retro-stage structure and tankage mass, m_{rst}	A4
retro-stage propellant mass, m_{rp}	A4
retro-maneuver incremental velocity, Δv	A4
retro-maneuver velocity loss	A4
final solar distance	A4
power at primary target	A4
case number	I2
card identifier	I2

Card 12	Format
launch Julian date	A4
flight time to primary target	A4
initial spacecraft mass, m_o	A4
power plant mass, m_{ps}	A4
propellant mass, m_p	A4
tankage mass, m_t	A4
structure mass, m_s	A4
reference power, p_{ref}	A4
efficiency, η	A4
net spacecraft mass, m_{net}	A4
reference thrust (newtons)	A4
maximum solar distance	A4
minimum solar distance	A4

Card 12 (cont)	Format
maximum power	A4
maximum thrust	A4
electric-propulsion burn time, τ	A4
travel angle, θ_t	A4
retro-maneuver burn time, t_b	A4
primary-target capture-orbit periapse-speed	A4
case number	I2
card identifier	I2

No information regarding intermediate targets is punched. It is not feasible to design a card-punch routine comprehensive enough to meet everybody's possible requirements, and therefore the user seriously contemplating using punched cards for summary purposes should design his or her own punched quantities and formats.

On option, the program will write the final trajectory on a magnetic tape, or punched cards, for input to the ASTEA program (see definition of input parameter MPUNCH). When punched, each trajectory point requires five cards. The content and format of these cards are as follows:

Card 1 — TI, WI, PRATIO, IEND, ITHR, where

(3D15.0, 2I2)

TI = the time since the start of the trajectory (days).

WI = the mass ratio, current mass over initial mass (unitless).

PRATIO = the power ratio, current power available over power available at one AU from the sun. For nuclear electric spacecraft, PRATIO = 1 always (unitless).

IEND = Flag which indicates last trajectory point.

= 0 not last trajectory point.
= 1 last trajectory point.

	ITHR =	Flag which indicates thrusting or coasting.
	= 1	Indicates thrusting (and thrust-on switching points).
	= 0	Indicates coasting (and thrust-off switching points).
Card 2	RI(I), I = 1, 2, 3; RDI(I), I = 1, 2, 3, where	
(6D12.0)	RI =	spacecraft position vector at current time-point (AU).
	RDI =	spacecraft velocity vector at current time-point (AU/tau).
Card 3	ELI(I), I = 1, 2, 3; CSI, where	
(4D15.0)	ELI =	solar radiation pressure unit vector.
	CSI =	solar radiation pressure coefficient c_s (AU^3/tau^2).
Card 4	PI(I), I = 1, 2, 3; PDI(I), I = 1, 2, 3, where	
(6D12.0)	PI =	target planet position vector at current time-point (AU).
	PDI =	target planet velocity vector at current time-point (AU/tau).
Card 5	ELAM(I), I = 1, 2, 3; ELAMD(I), I = 1, 2, 3, where	
(6D12.0)	ELAM =	Primer vector (Lagrange multipliers adjoint to spacecraft velocity), in any units. This is merely a vector which lies along the thrust vector.
	ELAMD =	time derivative of ELAM (any units/tau).

If the trajectory is output on tape, the contents of the tape are nothing more than the contents of the five cards described directly above. The format of each tape record is (30A8), so that each record consists of 30 words, each of length 8 in the A-format. The organization of the tape record is as follows:

TI, WI, PRATIO, ATHR, (RI(I), I = 1, 3),
(RDI(I), I = 1, 3), (ELI(I), I = 1, 3), CSI, (PI(I), I = 1,3),

(PDI(I), I = 1, 3), (ELAM(I), I = 1, 3), (ELAMD(I), I = 1, 3),
AEND, UNIDUM, UNIDUM, UNIDUM

where the names and their units are given directly above in the description of the cards. UNIDUM (universal dummy variable) represents unused words. Finally, ATHR and AEND are real variables which replace the integer quantities ITHR and IEND, respectively, which are punched on the cards.

D. JOB CONTROL FOR HILTOP

1. Program Execution. The HILTOP program is stored at the Goddard Space Flight Center IBM 360 model 91 computing facility in object module form as a member of a partitioned data set on a user disc pack. The job control cards sufficient to access and execute the program are as follows:

```
// EXEC LOADER,REGION.GO=344K,PARM='EP=MAIN,SIZE=344K'
//GO.SYSLIN DD DSN=MLOAD(ZOFMXHL),DISP=SHR,DCB=RECFM=
//GO.FT07F001 DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=80)
//GO.FT11F001 DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=80)
//GO.FT12F001 DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=80)
//GO.DATA5 DD *
```


The NAMELIST input data cards follow the last job control card listed above.

2. HILTOP Program Machine Requirements. When compiled on the IBM 360 Model 91 computer at the Goddard Space Flight Center under the Fortran H Level 21.7 compiler with the computer optimization level equal to two, the HILTOP program occupies approximately 312,000 decimal bytes in core. This includes the core requirements for the following IBM library subroutines which the program uses:

IHCCOMH2	IHCLATN2
IHCECOMH	IHCLEXP
IHCEFIOS	IHCLLOG
IHCEFNTH	IHCLSCN
IHCERRM	IHCLSQRT
IHCETRCH	IHCLTANH
IHCFCVTH	IHCNAMEL
IHCFDXPD	IHCUATBL
IHCFDXPI	IHCUOPT
IHCFIOS2	REMTIM
IHCLASCN	

The program is written almost entirely in double-precision Fortran IV using the non-standard Fortran statement IMPLICIT REAL*8 (A-H, O-Z). This results in the assignment of an 8-byte word location to each real variable name which begins with one of the letters A through H or O through Z, unless the name is specifically declared to be of another type. An 8-byte word contains 15 decimal digits on the machine cited. As in standard Fortran IV, names commencing with one of the letters I through N represent integer variables of 4-byte word length.

The peripheral equipment referenced by the HILTOP program is the card reader, assigned to unit 5, the high speed printer, assigned to unit 6, the card output, assigned to unit 7, and two arbitrary output devices, assigned to units 11 and 12. The execution step requirements of the program are a little less than 350,000 bytes of Main Core Storage.

IV. SAMPLE PROBLEMS AND RESULTS

A list of the necessary program inputs and a copy of the resulting printed output are presented in this section for each of eight sample problems. The sample problems were selected to display the use of most of the important features of the program. The first problem is an orbiter mission exhibiting the use of a high thrust retro engine and a launch vehicle with input reference characteristics; the second problem is an asteroid rendezvous mission and employs two cases to exhibit the indirect and the direct optimization techniques; the third problem is a deep space probe that makes use of the two-dimensional, open-angle formulation and yields the minimum flight time solution for specified net spacecraft mass; the fourth problem is a Jupiter flyby mission that displays the ballistic swingby continuation feature, the fixed cone angle feature, the constrained propulsion time feature, and the launch vehicle independent formulation; the fifth problem is an Encke rendezvous mission encountering two asteroids enroute; the sixth case is an extra-ecliptic mission that displays the housekeeping power option and exhibits the effects of high launch asymptote declinations on launch vehicle performance and the low thrust trajectory; the seventh case is a comet rendezvous mission which includes the effects of solar array degradation due to radiation effects; and the eighth and final case displays the HILTOP's powerful capability for ballistic mission design and optimization. The specific mission chosen is a cometary flyby past Giacobini-Zinner followed by a deep space burn 10 days after passage, a return to and swingby of Earth (unpowered), a second swingby of Earth (powered), and finally encountering the comet Borrelly nearly 1023 days from launch. The tremendous flexibility for creating imaginative, multi-target mission profiles is demonstrated in this example.

Machine-time quotes are not given for the sample problems because the machine-time values are not necessarily representative of the machine-time requirements for running the HILTOP program to perform the task of electric propulsion mission analysis. A single trajectory on the IBM 360 Model 91

computer takes from about .003 minutes of CPU time for "fast" missions such as direct outer-planet flybys to about .012 minutes for "slow" missions such as Mercury orbiters. However, it is not the time-per-trajectory that is important, but rather it is the total number of trajectories required in an iteration-sequence that counts, and quite often that number is not as small as in the sample problems displayed.

A. MERCURY ORBITER

The objective is to place maximum net spacecraft mass into a 1.2 by 22.8 radii orbit about the planet Mercury for specified launch date and flight time of 510 days. The analytic planetary ephemeris is employed to locate Earth and Mercury on the appropriate dates and to evaluate the initial and final state vectors. The long flight time for this mission (compared to ballistic transfers) is common to the class of optimum electric propulsion trajectories characterized by a $2\frac{1}{2}$ revolution spiral about the sun. Solar electric propulsion with power ratio Option 4 (i.e., peak power is maintained near the sun) is assumed. The booster parameters are input and represent the TAT (3C)/Delta/TE 364-3. The final capture orbit insertion maneuver is performed with a chemical retro stage, and the retro velocity increment computation includes the finite thrust velocity penalty.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X7=1.D0,X11(2)=1.D0,X12(2)=1.D0,X13(2)=1.D0,X14(2)=1.D0
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=1.D0,Y5(2)=1.D0,Y6(2)=1.D0
Y11(2)=1.D0,Y12(2)=1.D0,Y13(2)=1.D0,Y14(2)=1.D0,NPRINT=15,MTMASS=2
MOPT2=3,MOPT3=1,RPER=1.2D0,RAP=22.8D0,THRET=2.D1,JPP=1,JT=1,MBOOST=-1
B1=50315.832D0,B2=2199.9309D0,B3=44.45D0,MYEAR=1980,MONTH=2,MDAY=24
X1=-4.0719D-1,X2=3.92796D-1,X3=-1.7139D-1,X4=1.4431D-1,X5=4.3199D-1
X6=-7.0777D-1,X11=2.83699D-4,X12=4.2793D4,X13=4.5047D2,X14=1.41327D3
X16=5.1D2 &END
```

The entire electric propulsion system and the electric propulsion propellant tankage are jettisoned prior to the retro maneuver. The parameters optimized in this case include the reference thrust acceleration (and therefore the reference power), the jet exhaust speed, and the launch and arrival excess speeds. The NAMELIST input data set used to generate this case is reproduced above and the complete output obtained with NPRINT = 15 and MPRINT = 0 is displayed on the following pages.

CASE 1 TIME TO GO CPU 29. I/O 13 SEC

PROGRAM INPUTS

X 1 =	-4.0719000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 =	3.9279600000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 =	-1.7139000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 =	1.4431000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 =	4.3199000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 =	-7.0777000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 =	1.0000000000000000D 00,	0.0 .	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 =	0.0 .	0.0 .	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 =	0.0 .	0.0 .	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 =	0.0 .	0.0 .	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 =	2.8369900000000000D-04,	1.0000000000000000D 00,	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 =	4.2793000000000000D 04,	1.0000000000000000D 00,	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 =	4.5047000000000000D 02,	1.0000000000000000D 00,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 =	1.4132700000000000D 03,	1.0000000000000000D 00,	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 =	0.0 .	0.0 .	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 =	5.1000000000000000D 02,	0.0 .	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 =	0.0 .	0.0 .	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 =	0.0 .	0.0 .	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 =	0.0 .	0.0 .	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 =	0.0 .	0.0 .	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 =	0.0 .	0.0 .	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 =	0.0 .	0.0 .	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 =	0.0 .	0.0 .	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 =	0.0 .	0.0 .	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X59 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X60 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X61 =	0.0 .	0.0 .	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,

X62 =	[illegible]	[illegible]	[illegible]	[illegible]
X63 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,
X64 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,
X65 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,
X66 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,
X67 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999990D-05,
X68 =	0.0	0.0	5.0000000000000000D 01,	9.9999999999999990D-07,
X69 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,
X70 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,
Y 1 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y 2 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y 3 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y 4 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y 5 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y 6 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y 7 =	0.0	0.0	9.9999999999999990D-05,	
Y 8 =	0.0	0.0	9.9999999999999990D-05,	
Y 9 =	0.0	0.0	9.9999999999999990D-05,	
Y10 =	0.0	0.0	9.9999999999999990D-05,	
Y11 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y12 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y13 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y14 =	0.0	1.0000000000000000D 00,	9.9999999999999990D-05,	
Y15 =	0.0	0.0	9.9999999999999990D-05,	
Y16 =	0.0	0.0	9.9999999999999990D-05,	
Y17 =	0.0	0.0	9.9999999999999990D-05,	
Y18 =	0.0	0.0	9.9999999999999990D-05,	
Y19 =	0.0	0.0	9.9999999999999990D-05,	
Y20 =	0.0	0.0	9.9999999999999990D-05,	
Y21 =	0.0	0.0	9.9999999999999990D-05,	
Y22 =	0.0	0.0	9.9999999999999990D-05,	
Y23 =	0.0	0.0	9.9999999999999990D-05,	
Y24 =	0.0	0.0	9.9999999999999990D-05,	
Y25 =	0.0	0.0	9.9999999999999990D-05,	
Y26 =	0.0	0.0	9.9999999999999990D-05,	
Y27 =	0.0	0.0	9.9999999999999990D-05,	
Y28 =	0.0	0.0	9.9999999999999990D-05,	
Y29 =	0.0	0.0	9.9999999999999990D-05,	
Y30 =	0.0	0.0	9.9999999999999990D-05,	
Y31 =	0.0	0.0	9.9999999999999990D-05,	
Y32 =	0.0	0.0	9.9999999999999990D-05,	
Y33 =	0.0	0.0	9.9999999999999990D-05,	
Y34 =	0.0	0.0	9.9999999999999990D-05,	
Y35 =	0.0	0.0	9.9999999999999990D-05,	
Y36 =	0.0	0.0	9.9999999999999990D-05,	
Y37 =	0.0	0.0	9.9999999999999990D-05,	
Y38 =	0.0	0.0	9.9999999999999990D-05,	
Y39 =	0.0	0.0	9.9999999999999990D-05,	
Y40 =	0.0	0.0	9.9999999999999990D-05,	
Y41 =	0.0	0.0	9.9999999999999990D-05,	
Y42 =	0.0	0.0	9.9999999999999990D-05,	
Y43 =	0.0	0.0	9.9999999999999990D-05,	
Y44 =	0.0	0.0	9.9999999999999990D-05,	
Y45 =	0.0	0.0	9.9999999999999990D-05,	
Y46 =	0.0	0.0	9.9999999999999990D-05,	
Y47 =	0.0	0.0	9.9999999999999990D-05,	
Y48 =	0.0	0.0	9.9999999999999990D-05,	
Y49 =	0.0	0.0	9.9999999999999990D-05,	
Y50 =	0.0	0.0	9.9999999999999990D-05,	
Y51 =	0.0	0.0	9.9999999999999990D-05,	
Y52 =	0.0	0.0	9.9999999999999990D-05,	
Y53 =	0.0	0.0	9.9999999999999990D-05,	
Y54 =	0.0	0.0	9.9999999999999990D-05,	
Y55 =	0.0	0.0	9.9999999999999990D-05,	
Y56 =	0.0	0.0	9.9999999999999990D-05,	
Y57 =	0.0	0.0	9.9999999999999990D-05,	
[illegible]	[illegible]	[illegible]	[illegible]	

Last column for X63–X70: 1.0000000000000000D 00, (each row)

```
Y58 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y59 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y60 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y61 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y62 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y63 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y64 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y65 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y66 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y67 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y68 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y69 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
Y70 =  0.0              ,  0.0              ,  9.9999999999999990D-05,
&OUTPUT
AAI= 0.0               ,AE= 0.0              ,ALPHAA=  15.0000000000000   ,ALPHAT=  15.0000000000000    ,ALTITU=
 0.0               ,AN=  1.50000000000000    ,AR=  1.00000000000000    ,ASOL= 0.0               , 0.0              ,
 0.0               , 0.0              , 0.0              ,BI= 0.760000000000000    ,BI=  50315.8320000000    ,B2=
 2199.98090000000    ,B3=  44.4500000000000    ,CNI= 0.0              ,CNIX= 0.0             , 0.0              ,
 0.0               , 0.0              , 0.0              ,CSTR= 0.0              ,CTANK= 0.29999999999999990D-01,
CTRET= 0.111111111111111    ,DI=  13.0000000000000    ,DMRETR= 0.0              ,DPDW= 0.0              ,ECI=
 0.0               ,ECIX= 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               ,EI= 0.0               ,EMUDDD= 0.0              ,EMUDDX= 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              ,GAMMAX=  1.00000000000000    ,GAP=
 0.99999999999999990D-04,HOUR=  12.0000000000000    ,OMI= 0.0              ,OMIX= 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              ,POWFIX= -1.00000000000000    ,
PSIGN=  1.00000000000000    ,RADDDD=  1.00000000000000    ,RADDDX= 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              ,RAP=  22.8000000000000    ,REVS= 0.0              ,
RPER=  1.20000000000000    ,SAI=  1.00000000000000    ,SAIX= 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              ,SOI= 0.0              ,SOIX= 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              ,SPIRET=  300.000000000000    ,
STATE=  1.00000000000000    , 0.0              , 0.0              , 0.0              ,  1.00000000000000    ,
 0.0               ,STEP1= 0.31250000000000000D-01,STEP2= 0.125000000000000    ,TCOAST= 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              ,TDV= -1.00000000000000    ,TGO=
-1.00000000000000    ,THRET=  20.0000000000000    ,TOFF= -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    ,TPI= 0.0              ,TPIX= 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              ,TPOWER= 0.10000000000000000D 31,TSCALE=
 1.00000000000000    ,T2=  50.0000000000000    , 100.000000000000    , 150.000000000000    , 200.000000000000    ,
 250.000000000000    , 300.000000000000    , 350.000000000000    , 400.000000000000    , 450.000000000000    ,
 500.000000000000    ,XANG1= 0.0              ,XANG2= 0.0              ,XSWING= 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              , 0.0              ,
 0.0               , 0.0              , 0.0              , 0.0              ,X0=  1.00000000000000    ,
 0.0               , 0.0              , 0.0              ,  1.00000150000000    , 0.0              ,
 0.0               ,IBAL=          0,INTPR=          0,IOUT=          0,IRK=          1,IRL=          1,IROT=          0,ISPIN=
          0,ITF=          3,ITPRNT=          0,JPP=          1,JPRINT=          0,JT=          1,KPART=          0,LAUNCH=
          0,LOADX=          0,MAXHAM=          5,MBOOST=         -1,MDAY=         24,MODE=          4,MONTH=          2,MOPT=
          0,MOPTX=          0,          0,          0,          0,          0,MOPT2=          3,MOPT3=          1,MOPT4=          0,
          0,          0,          0,          0,          0,          0,          0,          0,MPOW=          0,
MPRINT=          0,MPUNCH=          0,MREAD=          0,MSWING=          0,          0,          0,          0,          0,
          0,          0,          0,          0,MTMASS=          2,MUPDAT=          1,MYEAR=       1980,NDIST=
          3,NHUNG=         25,NORMAL=          0,NPERF=          0,NPRINT=         15,NSET=          0,          0,        300,
          0,        300,NSWING=          0,NSWPAR=          1,NTAPE=         17
&END
```

ORIGINAL PAGE IS
OF POOR QUALITY

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	-4.0719000000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	3.9279600000000000D-01	3.0000000000000000D 00	1.0000000000000000D-06	1.0000000000000000D 00
3	3	-1.7139000000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	1.4431000000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	4.3199000000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	-7.0777000000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	11	2.8369900000000000D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
8	12	4.2793000000000000D 04	2.0000000000000000D 03	9.9999999999999990D-04	1.0000000000000000D 00
9	13	4.5047000000000000D 02	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00
10	14	1.4132700000000000D 03	5.0000000000000000D 02	9.9999999999999990D-04	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	11	0.0	9.9999999999999990D-05
8	12	0.0	9.9999999999999990D-05
9	13	0.0	9.9999999999999990D-05
10	14	0.0	9.9999999999999990D-05

```
---------- NOMINAL TRAJECTORY  1 (TOTAL    1) ---------- INHIBITOR IS    5.8208D-11 -------------------------------------------
                                                   INDEPENDENT PARAMETERS
  1.PRIM1(-4.0719000D-01)    2.PRIM2( 3.9279600D-01)    3.PRIM3(-1.7139000D-01)    4.PDOT1( 1.4431000D-01)    5.PDOT2( 4.3199000D-01)
  6.PDOT3(-7.0777000D-01)   11.ACCEL( 2.8369900D-04)   12.V JET( 4.2793000D 04)   13.VINF1( 4.5047000D 02)   14.VINF2( 1.4132700D 03)
                                                    DEPENDENT PARAMETERS
  1.DELTA X(-1.08128D-04)    2.DELTA Y( 4.70325D-04)    3.DELTA Z( 4.99616D-05)    4.DELT XD(-2.13015D-03)    5.DELT YD(-3.00546D-04)
  6.DELT ZD( 1.74281D-04)   11.T.ACCEL( 5.85136D-03)   12.T.V JET(-3.39038D-02)   13.T.VINF1( 4.03733D-03)   14.T.VINF2( 1.45919D-02)
THRUST SWITCHING TIMES (DAYS)         0.0     OFF      11.408   ON      173.223  OFF     197.020   ON      510.000   ON
                                               ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY           PROP TIME                J                 PROP TIME RATIO        AVE ACCEL
      2.5294326125        0.6957877327        474.7945112005          6.4008076352        0.9309696298           0.0003505991
                                                  MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION           PROPELLANT             TANKAGE             STRUCTURE              PAYLOAD
    289.9341274985       75.8829783739       100.0915169599           3.0027485088        0.0                   97.0793021053

 -2.03020D 01  4.65240D 00 -1.08167D 00 -1.52196D 01 -1.52598D 01 -2.31309D-01  4.09557D 01  1.00933D 00  1.19470D 01  0.0

  9.10706D 01 -2.02643D 01  4.83546D 00  6.83426D 01  6.91253D 01  1.29946D 00 -1.41899D 02 -4.52864D 00 -5.06879D 01  0.0

  9.58204D 00 -2.16650D 00  5.29826D-01  7.16650D 00  7.25732D 00  9.37246D-02 -1.46289D 01 -4.70949D-01 -5.39545D 00  0.0

 -4.12732D 02  9.11220D 01 -2.19021D 01 -3.09888D 02 -3.11925D 02 -5.69685D 00  6.49429D 02  2.35846D 01  2.30652D 02 -2.42347D-07

 -5.31005D 01  1.09465D 01 -2.82472D 00 -3.99668D 01 -4.05184D 01 -1.02237D 00  4.55464D 01  2.62125D 00  2.67823D 01  9.69912D-01

  3.46030D 01 -7.58995D 00  2.13237D 00  2.60731D 01  2.61359D 01  6.47978D-01 -6.03407D 01 -1.80220D 00 -2.01586D 01  2.32049D-02

  9.16283D 00 -3.68005D 00  1.92015D-01  5.41892D 00  8.12303D 00  2.48081D-01  8.87888D 00 -1.91087D-02 -3.85915D 00 -2.89344D-09

  9.53535D-01  5.25568D-01  2.00414D-01  1.30379D 00  9.92933D-02  4.59356D-02  1.37421D 01  1.16795D 00 -8.54762D-01  0.0

  4.09292D 00 -1.11444D 00 -4.08819D-01  3.00738D 00  4.75932D 00  1.43723D-01  8.21706D 00  9.23325D-03 -6.85121D 01  0.0

 -2.66465D 01  7.35022D 00 -1.24987D 00 -1.88328D 01 -2.11259D 01 -3.10569D-01  6.32828D 01  1.17920D 00  1.52091D 01 -1.99256D 01


---------- NOMINAL TRAJECTORY  2 (TOTAL    4) ---------- INHIBITOR IS    1.8190D-12 -------------------------------------------
                                                   INDEPENDENT PARAMETERS
  1.PRIM1(-4.0044042D-01)    2.PRIM2( 3.9195423D-01)    3.PRIM3(-1.7495654D-01)    4.PDOT1( 1.3490148D-01)    5.PDOT2( 4.3093968D-01)
  6.PDOT3(-7.0595550D-01)   11.ACCEL( 2.8392901D-04)   12.V JET( 4.2094555D 04)   13.VINF1( 4.4731935D 02)   14.VINF2( 1.3799611D 03)
                                                    DEPENDENT PARAMETERS
  1.DELTA X( 3.84522D-04)    2.DELTA Y(-1.78557D-03)    3.DELTA Z(-1.63504D-04)    4.DELT XD( 8.05597D-03)    5.DELT YD( 1.00886D-03)
  6.DELT ZD(-7.08456D-04)   11.T.ACCEL(-3.98530D-04)   12.T.V JET(-2.95844D-04)   13.T.VINF1(-2.42275D-04)   14.T.VINF2( 1.72180D-04)
THRUST SWITCHING TIMES (DAYS)         0.0     OFF      12.645   ON      173.054  OFF     197.556   ON      510.000   ON
                                               ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY           PROP TIME                J                 PROP TIME RATIO        AVE ACCEL
      2.4973734201        0.6938262711        472.8534868844          6.4340506769        0.9271636998           0.0003521556
                                                  MASS COMPONENT BREAKDOWN
```

INITIAL	PROPULSION	PROPELLANT	TANKAGE	STRUCTURE	PAYLOAD
289.9536170432	74.9212026040	101.4576814505	3.0440304435	0.0	97.1277249796

-2.00111D 01	4.58135D 00	-1.06736D 00	-1.49993D 01	-1.50572D 01	-2.45770D-01	4.00063D 01	1.02558D 00	1.20365D 01	0.0
9.23247D 01	-2.05207D 01	4.90197D 00	6.92729D 01	7.02137D 01	1.39713D 00	-1.41532D 02	-4.73438D 00	-5.25069D 01	0.0
9.65544D 00	-2.18073D 00	5.33084D-01	7.22018D 00	7.33708D 00	1.02415D-01	-1.45097D 01	-4.89109D-01	-5.55470D 00	0.0
-4.17952D 02	9.21634D 01	-2.21749D 01	-3.13767D 02	-3.15432D 02	-6.12958D 00	6.47094D 02	2.14940D 01	2.38583D 02	-2.35991D-01
-5.11108D 01	1.04992D 01	-2.71248D 00	-3.84678D 01	-3.92231D 01	-1.03248D 00	4.12502D 01	2.60152D 00	2.62376D 01	9.71509D-01
3.53064D 01	-7.73821D 00	2.17000D 00	2.65980D 01	2.67257D 01	6.90543D-01	-6.04667D 01	-1.69465D 00	-2.09902D 01	2.18838D-02
9.52256D 00	-3.81654D 00	1.98131D-01	5.63170D 00	8.44173D 00	2.57987D-01	8.90729D 00	-4.46477D-02	-4.14283D 00	0.0
8.96708D-01	5.20463D-01	1.93232D-01	1.25060D 00	7.90533D-02	4.66685D-02	1.33756D 01	1.14921D 00	-8.18333D-01	-6.61358D-09
4.09240D 00	-1.10900D 00	-4.27279D-01	2.99267D 00	4.75352D 00	1.43172D-01	8.30200D 00	-1.83233D-03	-6.87601D 01	2.89344D-09
-2.65131D 01	7.30444D 00	-1.24315D 00	-1.87333D 01	-2.10525D 01	-3.31163D-01	6.19514D 01	1.19529D 00	1.54620D 01	-2.01425D 01

THIS CASE IS CONVERGED.

5 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 2 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			START OF TRAJECTORY, THRUST OFF				
0.0	9.91022884D-01	2.66559535D-02	2.55113449D-01	3.35044091D 02	1.83000000D 02	9.89636705D-01	0.0
-8.97237034D-01	4.17548216D-01	0.0	-4.48542837D-01	-9.00374607D-01	-4.47734940D-03	1.00000000D 00	4.85112587D-02
-4.00484325D-01	3.92107905D-01	-1.75004456D-01	1.34753358D-01	4.31056680D-01	-7.36215376D-01	1.00000000D 00	-9.42647784D-02
0.0	0.0	0.0	9.89462875D 01	3.24202698D 02	9.95147588D-01	1.01326757D 00	-1.20503242D-01
-1.74252514D 01	-1.93632603D 01	2.58235594D 01	0.0	1.55044091D 02	1.52535119D 00	1.00592505D 00	0.0
			SWITCH THRUST ON				
1.26352078D 01	9.91022884D-01	2.66559535D-02	2.55113449D-01	3.35044091D 02	1.92580016D 02	9.95426441D-01	1.25800156D 01
-9.72294351D-01	2.13346110D-01	-9.65343742D-04	-2.39934415D-01	-9.70846584D-01	-4.35993476D-03	1.00000000D 00	4.81553634D-02
-3.96765777D-01	4.88881435D-01	-3.23057818D-01	-1.00209382D-01	4.42705827D-01	-6.50845399D-01	1.00000000D 00	-9.42647784D-02
0.0	0.0	0.0	9.64052400D 01	3.22105964D 02	9.95147588D-01	1.00583389D 00	-5.55111512D-17
-2.72736716D 01	-3.84440474D 01	4.58815532D 01	-5.55642572D-02	1.67623986D 02	1.50609279D 00	1.00006535D 00	0.0
			SWITCH THRUST OFF				
1.73091936D 02	8.06788706D-01	1.99803205D-01	3.20986623D 00	4.99458120D 01	2.75264701D 02	8.34843277D-01	1.70119970D 02
6.84620000D-01	-4.75491311D-01	-4.65485410D-02	4.28013575D-01	9.86248037D-01	1.72195296D-02	9.03366866D-01	6.50168400D-02
-4.29794469D-01	-6.02518118D-01	5.41605099D-02	1.07147640D 00	-3.55228317D-01	7.85319339D-01	1.16080050D 00	-9.42647792D-02
-1.01572084D 00	-7.38178157D-02	0.0	8.24655447D 01	2.55593286D 02	8.80102628D-01	1.22679392D 00	2.63677968D-16
4.43355008D 00	-9.09531545D 01	9.09503021D 01	-3.19631105D 00	-3.47812515D 01	-1.13541655D 01	1.07525686D 00	1.60456728D 02
			SWITCH THRUST ON				
1.97499346D 02	8.06788706D-01	1.99803205D-01	3.20986623D 00	4.99458120D 01	3.09446794D 02	7.41255570D-01	2.04302063D 02
7.40526533D-01	-7.28002828D-03	-3.20511239D-02	-2.07491031D-01	1.19865749D 00	5.18044403D-02	9.03366866D-01	7.14402194D-02
6.89996532D-02	-6.47873756D-01	3.55222992D-01	1.27575603D 00	1.84410002D-01	5.92509255D-01	1.16080050D 00	-9.42647792D-02
-1.01572084D 00	-7.38178157D-02	0.0	8.87620052D 01	2.27366800D 02	8.80102628D-01	1.34799579D 00	-1.38777878D-17
3.08890287D 01	-8.45995920D 01	8.53673815D 01	-2.47818234D 00	-5.63249849D-01	-1.05534315D 01	1.20774287D 00	1.60456728D 02
MERCURY			END OF TRAJECTORY, THRUST ON				
5.10000000D 02	4.13611608D-01	2.37076614D-01	6.92030152D 00	4.87890034D 01	3.15323870D 02	3.49765348D-01	9.29011650D 02
3.47516799D-01	2.62660752D-02	-2.96304944D-02	-4.49886030D-01	1.75077288D 00	1.81077644D-01	6.49946321D-01	1.02855736D-01
8.75435120D-01	-3.53042157D 00	-7.97050634D-02	1.68926007D 01	1.70553973D 00	-1.90669805D-01	2.50547409D 00	-9.42639153D-02
-1.31260524D 01	-3.67252947D-01	0.0	9.22387098D 01	2.56498509D 02	6.24791513D-01	1.39632851D 00	2.48583216D 00
4.42145543D 00	-8.02958102D 01	8.03249684D 01	-4.85965657D 00	4.32232141D 00	-1.04932777D 01	1.81669817D 00	4.72957382D 02

CASE 1

ITERATOR SUMMARY

```
                                           INDEPENDENT PARAMETERS

 1,PRIM1(-4.0048432D-01 )  2,PRIM2( 3.92107900-01)  3,PRIM3(-1.7500446D-01)  4,PDOT1( 1.3475336D-01)  5,PDOT2( 4.3105668D-01)
 6,PDOT3(-7.0621538D-01 )  7,LMASS( 1.0000000D 00)  8, LTAU( 0.0          )  9,     ( 0.0          ) 10,DECLN( 0.0          )
11,ACCEL( 2.8391117D-04 ) 12,V JET( 4.2088807D 04) 13,VINF1( 4.4743351D 02) 14,VINF2( 1.3804648D 03) 15,TIME1( 0.0          )
16,TIME2( 5.1000000D 02 ) 17,IPARK( 0.0          ) 18,VEL01( 0.0          ) 19,VEL02( 0.0          ) 20,VEL03( 0.0          )
21,THET1( 0.0           ) 22,THET2( 0.0          ) 23,THET3( 0.0          ) 24,THET4( 0.0          ) 25,THET5( 0.0          )
26,THET6( 0.0           ) 27,THET7( 0.0          ) 28,THET8( 0.0          ) 29,THET9( 0.0          ) 30,LDEGR( 0.0          )
31, PHI1( 0.0           ) 32, PHI2( 0.0          ) 33, PHI3( 0.0          ) 34, PHI4( 0.0          ) 35, PHI5( 0.0          )
36, PHI6( 0.0           ) 37, PHI7( 0.0          ) 38, PHI8( 0.0          ) 39, PHI9( 0.0          ) 40,PHI10( 0.0          )
41,PR1-A( 0.0           ) 42,PR2-A( 0.0          ) 43,PR3-A( 0.0          ) 44,PD1-A( 0.0          ) 45,PD2-A( 0.0          )
46,PD3-A( 0.0           ) 47,VINFA( 0.0          ) 48,TIMEA( 0.0          ) 49,KSAMP( 0.0          ) 50,KDROP( 0.0          )
51,PR1-B( 0.0           ) 52,PR2-B( 0.0          ) 53,PR3-B( 0.0          ) 54,PD1-B( 0.0          ) 55,PD2-B( 0.0          )
56,PD3-B( 0.0           ) 57,VINFB( 0.0          ) 58,TIMEB( 0.0          ) 59,KSAMP( 0.0          ) 60,KDROP( 0.0          )
61,PR1-C( 0.0           ) 62,PR2-C( 0.0          ) 63,PR3-C( 0.0          ) 64,PD1-C( 0.0          ) 65,PD2-C( 0.0          )
66,PD3-C( 0.0           ) 67,VINFC( 0.0          ) 68,TIMEC( 0.0          ) 69,KSAMP( 0.0          ) 70,KDROP( 0.0          )

                                            DEPENDENT PARAMETERS

 1,DELTA X(-4.57978D-06)   2,DELTA Y( 9.61822D-07)   3,DELTA Z( 5.45226D-07)   4,DELT XD(-1.10562D-05)   5,DELT YD(-2.22841D-05)
 6,DELT ZD(-9.13386D-07)   7,       ( 0.0        )   8,       ( 0.0        )   9,       ( 0.0        )  10,       ( 0.0        )
11,T,ACCEL(-2.50253D-07)  12,T,V JET( 2.39545D-08)  13,T,VINF1(-2.95989D-08)  14,T,VINF2(-1.96493D-07)  15,       ( 0.0        )
16,       ( 0.0        )  17,       ( 0.0        )  18,       ( 0.0        )  19,       ( 0.0        )  20,       ( 0.0        )
21,       ( 0.0        )  22,       ( 0.0        )  23,       ( 0.0        )  24,       ( 0.0        )  25,       ( 0.0        )
26,       ( 0.0        )  27,       ( 0.0        )  28,       ( 0.0        )  29,       ( 0.0        )  30,       ( 0.0        )
31,       ( 0.0        )  32,       ( 0.0        )  33,       ( 0.0        )  34,       ( 0.0        )  35,       ( 0.0        )
36,       ( 0.0        )  37,       ( 0.0        )  38,       ( 0.0        )  39,       ( 0.0        )  40,       ( 0.0        )
41,       ( 0.0        )  42,       ( 0.0        )  43,       ( 0.0        )  44,       ( 0.0        )  45,       ( 0.0        )
46,       ( 0.0        )  47,       ( 0.0        )  48,       ( 0.0        )  49,       ( 0.0        )  50,       ( 0.0        )
51,       ( 0.0        )  52,       ( 0.0        )  53,       ( 0.0        )  54,       ( 0.0        )  55,       ( 0.0        )
56,       ( 0.0        )  57,       ( 0.0        )  58,       ( 0.0        )  59,       ( 0.0        )  60,       ( 0.0        )
61,       ( 0.0        )  62,       ( 0.0        )  63,       ( 0.0        )  64,       ( 0.0        )  65,       ( 0.0        )
66,       ( 0.0        )  67,       ( 0.0        )  68,       ( 0.0        )  69,       ( 0.0        )  70,       ( 0.0        )

THRUST SWITCHING TIMES (DAYS)      0.0   OFF     12.635  ON     173.092  OFF     197.499  ON     510.000  ON

                                     ELECTRIC PROPULSION PARAMETERS
   POWER             EFFICIENCY          PROP TIME               J             PROP TIME RATIO        AVE ACCEL
 2.4969288756       0.6938097710      472.9573822833      6.4358551287         0.9273674162        0.0003521630

                                        MASS COMPONENT BREAKDOWN
   INITIAL           PROPULSION          PROPELLANT           TANKAGE            STRUCTURE            PAYLOAD
 289.9529132362     74.9078662679      101.4990840701       3.0449725221         0.0                97.1039758380

SWITCH-COUNT HISTORY   ALL 5

   504 THRUST COMPUTE STEPS,     7 COAST COMPUTE STEPS
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION		THRUST ANGLES PSI		THRUST ANGLES THETA		THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.990		154.2		0.0	OFF	-1.21D-01		*****		******		*****		0.0	ON	90.0
5	12.635	12.6		0.995		144.4		0.00	ON	-5.55D-17		-27.3		-38.4		45.9		2.5		0.0
4	65.595	63.0		1.016		102.1		0.04		5.19D-01	MIN	-36.5		-75.7		78.6		2.4		0.0
4	67.711	64.9	MAX	1.016		100.6		0.04		5.29D-01		-36.6		-76.5		79.2	MIN	2.4		0.0
4	86.169	81.9		1.012		87.8		0.06	MAX	5.71D-01		-35.9		-82.1		83.6		2.5		0.0
4	156.507	150.7		0.891		22.5		0.14		1.15D-01		-12.2	MIN	-92.0		92.0		2.9		0.0
4	157.423	151.7		0.888		21.8		0.14		1.03D-01		-11.4		-92.0	MAX	92.0		2.9		0.0
6	168.742	164.8		0.850	MIN	17.1		0.17		2.32D-02		-0.5		-91.5		91.5		3.0		0.0
4	173.092	170.2		0.835		17.7		0.19	OFF	2.54D-16		4.4		-91.0		91.0		3.1		0.0
5	185.000	185.9		0.790		23.6		0.25	MIN	-2.73D-02		*****		******		*****		0.0		90.0
5	197.499	204.4		0.741		30.7		0.33	ON	-1.39D-17		30.9		-84.5		85.4		3.4		0.0
4	216.192	236.5		0.677		37.6		0.50		1.04D-01	MAX	38.9		-77.2		80.0		3.5		0.0
4	220.653	245.0	*	0.665		38.5		0.55		1.33D-01		38.4		-75.7		78.9	MAX	3.5		0.0
4	234.922	273.5		0.639		39.7		0.71		2.29D-01		31.5	MAX	-73.7		76.2		3.5		22.7
6	235.917	275.5		0.638	MAX	39.7		0.72		2.35D-01		30.8		-73.7		76.1		3.5		23.1
3	242.574	289.3		0.634		39.5		0.80		2.91D-01		25.2		-74.2	MIN	75.8		3.5		24.9
4	245.191	294.8	MIN	0.633		39.3		0.83		3.15D-01		22.8		-74.5		75.8		3.5		25.0
4	273.470	350.9	*	0.665		35.7		1.13		7.05D-01		-2.3		-80.5		80.5		3.5		0.0
7	316.950	421.4	MAX	0.721		28.7		1.41		1.25D 00		-18.1		-85.2		85.5	MIN	3.4		0.0
7	323.064	430.4		0.719		27.6		1.43		1.29D 00		-18.4	MIN	-85.3		85.5		3.4		0.0
5	323.112	430.5		0.719		27.6		1.43		1.29D 00		-18.4		-85.3	MAX	85.5		3.4		0.0
4	323.661	431.3		0.719		27.5		1.43		1.29D 00	MIN	-18.4		-85.3		85.5		3.4		0.0
4	332.315	444.1		0.710		25.7		1.45	MAX	1.30D 00		-17.9		-85.1		85.4		3.4		0.0
4	351.450	474.0	*	0.665		20.6		1.49		1.25D 00		-13.6		-83.9		84.1	MAX	3.5		0.0
6	369.824	508.1		0.588		13.6	MAX	1.50		1.19D 00		-4.6		-81.7		81.8		3.5		38.6
5	371.531	511.8		0.579		12.8		1.50	MIN	1.19D 00		-3.6		-81.5		81.5		3.5		40.7
4	384.968	544.6		0.507		5.4		1.49		1.25D 00		4.5		-80.5	MIN	80.6		3.5		54.4
4	385.474	546.0		0.505		5.1		1.49		1.25D 00		4.8	MAX	-80.5		80.6		3.5		54.9
4	392.797	568.1		0.467	MIN	1.4		1.46		1.33D 00		8.2		-81.0		81.1		3.5		60.5
5	403.205	604.9		0.427		8.0		1.39		1.48D 00	MAX	10.2		-83.5		83.6		3.5		65.7
4	411.508	637.5	MIN	0.416		14.5		1.30		1.59D 00		8.9		-86.8		86.8		3.5		67.0
5	436.577	726.2		0.484		28.6		0.91		1.75D 00		-3.8		-92.7	MAX	92.7		3.5		58.0
4	436.677	726.5		0.484		28.7		0.91		1.75D 00		-3.9	MIN	-92.7		92.7		3.5		58.0
4	445.877	751.2		0.516	MAX	30.0		0.77		1.79D 00		-8.1		-92.1		92.1		3.5		53.0
4	463.764	792.3	MAX	0.544		23.4		0.56		1.84D 00		-11.8		-88.3		88.3		3.5		48.0
4	464.708	794.4		0.544		22.6		0.56		1.85D 00	MIN	-11.8		-88.0		88.1		3.5		46.0
4	477.499	822.8		0.525		8.1	MIN	0.50		1.37D 00		-10.0		-84.0		84.1		3.5		51.4
6	482.067	833.6		0.510	MIN	4.5		0.51		1.39D 00		-8.6		-82.5		82.6		3.5		53.9
4	501.003	889.9		0.407		19.9		0.74		2.17D 00		0.7		-78.3	MIN	78.3		3.5		68.0
4	501.035	890.0		0.407		19.9		0.74		2.17D 00		0.7	MAX	-78.3		78.3		3.5		66.0
4	505.794	909.5		0.376	MAX	20.8		0.85		2.33D 00		2.9		-78.8		78.8		3.5		71.4
4	510.000	929.3		0.350		20.1		0.95	ON	2.49D 00		4.4		-80.3		80.3		3.5	ON	74.0

MISSION SCHEDULE

FEBRUARY 24, 1980 1.20000000D 01 G.M.T.
2444294.0000D 00 JULIAN DATE — DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-8.9723703D-01	4.1754822D-01	0.0	-4.3829582D-01	-9.1040637D-01	0.0	9.8963670D-01	0.0	155.044
S/C	-8.9723703D-01	4.1754822D-01	0.0	-4.4854289D-01	-9.0037461D-01	-4.4773494D-03	9.8963670D-01	0.0	155.044

JULY 18, 1981 1.20000000D 01 G.M.T.
2444804.0000D 00 JULIAN DATE — PASS MERCURY AT 1.380 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	3.4752138D-01	2.6265113D-02	-2.9631040D-02	-4.3872257D-01	1.7058206D 00	1.9006318D-01	3.4976987D-01	-4.860	4.322
S/C	3.4751680D-01	2.6266075D-02	-2.9630494D-02	-4.4938603D-01	1.7507729D 00	1.8107764D-01	3.4976535D-01	-4.860	4.322

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND MERCURY IS 209.6433 DEGREES.

C-3

CASE 1 (CONVERGED) PERFORMANCE SUMMARY

EARTH TO MERCURY RENDEZ WITH HIGH THRUST CAPTURE MANEUVER.

LAUNCH VEHICLE IS INPUT (COEFFICIENTS = 50315.8320 2199.9809 44.4500)

LD = FEB 24, 1980, 12.0000 HOURS GMT AD = JUL 19, 1981, 12.0000 HOURS GMT FLIGHT TIME = 510.0000 DAYS.
JULIAN DATE 44294.0000 JULIAN DATE 44804.0000

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.0000	0.0300	0.0	0.76300	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
289.9529	74.9079	101.4991	3.0450	0.0	97.1040

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
2.4969	0.0	3.4865	0.082321	2.839112D-04	4291.864	0.69381	1.0000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
1.0157910	0.3497653	3.486533	0.11494699	472.95738	853.83930	929.01165

POWERPLANT JETTISONED PRIOR TO RETRO MANEUVER
TANKAGE MASS JETTISONED PRIOR TO RETRO MANEUVER

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-0.4403	28.5000	447.43351	0.200197	1380.46478	1.905683

HIGH THRUST CAPTURE MANEUVER STAGE AND ORBIT SUMMARY

STRUCTURE (KG)	PROPELLANT (KG)	THRUST (LBS)	ISP (SEC)	BURNING TIME (SEC)
1.3397	12.0573	20.0000	300.0000	40.6589

PERIAPSE (RADII)	APOAPSE (RADII)	ORBIT VEL (M/SEC)	DEL VEL (M/SEC)	VEL LOSS (M/SEC)
1.2000	22.8000	3711.9977	339.9173	1.0123

B. CERES RENDEZVOUS

The objective of this mission is to rendezvous with the asteroid Ceres with maximum net spacecraft mass. The rendezvous is accomplished by simply matching the heliocentric position and velocity of Ceres on the arrival date. Except for the launch excess speed provided by the Titan III B (Core)/Centaur, the entire mission is performed by a solar electric propulsion system, i.e., no retro stage is employed. To show how one inputs an arbitrary planet ephemeris for a primary target, the orbital elements of Ceres are input directly; however, the same results would be obtained for this case by setting MOPT3 = 10. Although the launch and arrival dates are left open, the flight time is constrained to 655 days. The program optimizes the reference thrust acceleration, the jet exhaust speed, the launch excess speed, and the launch and arrival dates. Rendezvous is achieved by driving the arrival excess speed to zero, and retro-stage mass computations are bypassed by setting MTMASS = 3.

The output for two separate cases is shown for this mission. The first case depicts the solution as obtained using the indirect method involving the satisfaction of the appropriate transversality conditions. Because the inputs were very close to the desired solution and because the indirect method generally exhibits quadratic convergence characteristics in the vicinity of the solution, only four iterations were required for convergence. The second case displays the use of the direct optimization capability of the program. This method ignores the transversality conditions and attempts to improve the performance index directly while maintaining approximate satisfaction of the specified end conditions. Note that this case is simply added behind the first case on a single run submittal. Using the value of MUPDAT = 0 assures that the independent variables of the two cases are identical. Starting from the same initial conditions as case 1, the direct optimization procedure requires 33 iterations to converge.

This example is somewhat unfair to the direct method in that it only shows the input setup; it shows neither the strong convergence property of the direct method when the inputs are far from the solution nor the flexibility of the method in choosing the performance index. It does show, however, that considerable machine time is required once the iteration approaches the desired solution. The inputs for the two cases are listed below, followed by the program output for the two cases resulting from the settings of NPRINT = 3 and MPRINT = 0.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X11(2)=1.D0,X12(2)=1.D0,X13(2)=1.D0,X15(2)=1.D0,X16(2)=1.D0
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=1.D0,Y5(2)=1.D0,Y6(2)=1.D0
Y11(2)=1.D0,Y12(2)=1.D0,Y13(2)=1.D0,Y15(2)=1.D0,Y16=655.D0,3.D0
NPRINT=3,MUPDAT=0,LAUNCH=0,NORMAL=1,MBOOST=10,ALPHAA=12.5D0,MTMASS=3
ALPHAT=12.5D0
MOPT2=3,MOPT3=11,MYEAR=1976,MONTH=11,MDAY=19,HOUR=6.523D0,X7=.296D0
SAI=2.7675D0,ECI=.0759D0,CNI=10.607D0,OMI=80.513748D0,SOI=71.8529182D0
X1=6.771D-1,X2=6.588D-4,X3=-2.533D-1,X4=-1.142D-1,X5=4.983D-1
X6=8.374D-2,X11=4.487D-4,X12=3.184D4,X13=1.546D3,X15=-5.1D2
X16=1.449D2 &END
&MINPUT Y11(2)=0.D0,Y12(2)=0.D0,Y13(2)=0.D0,Y15(2)=0.D0
Y7=1.D3,3.D0,0.D0,MPERF=7 &END
```

CASE 1   TIME TO GO   CPU 298. I/O 43 SEC

PROGRAM INPUTS

X 1 =	2.287500000000000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 2 =	2.225675675675675D-03,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 3 =	-8.557432432432432D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 4 =	-3.858108108108108D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 5 =	1.583445945945946D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 6 =	2.997972972972973D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 7 =	1.000000000000000D 00,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X 8 =	0.0 ,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X 9 =	0.0 ,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X10 =	0.0 ,	0.0 ,	9.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X11 =	4.487000000000000D-04,	1.000000000000000D 00,	9.999999999999999D-04,	1.000000000000000D-11,	1.000000000000000D 00,
X12 =	3.184000000000000D 04,	1.000000000000000D 00,	2.000000000000000D 03,	9.999999999999999D-04,	1.000000000000000D 00,
X13 =	1.546000000000000D 03,	1.000000000000000D 00,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X14 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-04,	1.000000000000000D 00,
X15 =	-5.100000000000000D 02,	1.000000000000000D 00,	8.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X16 =	1.449000000000000D 02,	1.000000000000000D 00,	1.000000000000000D 02,	9.999999999999999D-07,	1.000000000000000D 00,
X17 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X18 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X19 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X20 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X21 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X22 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X23 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X24 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X25 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X26 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X27 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X28 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X29 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X30 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X31 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X32 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X33 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X34 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X35 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X36 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X37 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X38 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X39 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X40 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X41 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X42 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X43 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X44 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X45 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X46 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X47 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X48 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X49 =	0.0 ,	0.0 ,	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X50 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X51 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X52 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X53 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X54 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X55 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X56 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X57 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X58 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X59 =	0.0 ,	0.0 ,	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X60 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00

```
X61 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X62 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X63 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X64 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X65 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X66 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X67 = 0.0                      , 0.0                      , 5.0000000000000000D 02, 9.9999999999999999D-05, 1.0000000000000000D 00,
X68 = 0.0                      , 0.0                      , 5.0000000000000000D 01, 9.9999999999999999D-07, 1.0000000000000000D 00,
X69 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
X70 = 0.0                      , 0.0                      , 3.0000000000000000D 00, 1.0000000000000000D-08, 1.0000000000000000D 00,
Y 1 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y 2 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y 3 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y 4 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y 5 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y 6 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y 7 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y 8 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y 9 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y10 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y11 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y12 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y13 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y14 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y15 = 0.0                      , 1.0000000000000000D 00, 9.9999999999999999D-05,
Y16 = 6.5500000000000000D 02, 3.0000000000000000D 00, 9.9999999999999999D-05,
Y17 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y18 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y19 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y20 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y21 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y22 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y23 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y24 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y25 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y26 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y27 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y28 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y29 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y30 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y31 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y32 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y33 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y34 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y35 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y36 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y37 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y38 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y39 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y40 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y41 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y42 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y43 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y44 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y45 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y46 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y47 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y48 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y49 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y50 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y51 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y52 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y53 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y54 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
Y55 = 0.0                      , 0.0                      , 9.9999999999999999D-05,
```

```
Y56 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y57 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y58 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y59 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y60 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y61 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y62 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y63 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y64 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y65 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y66 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y67 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y68 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y69 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
Y70 =  0.0                    ,  0.0              ,  9.5555555555555550D-05,
&OUTPUT
AXI= 0.0           ,AE= 0.0              ,ALPHAA=  12.500000000000000   ,ALPHAT=  12.500000000000000   ,ALTITU=
 0.0              ,AN=  1.5000000000000000   ,AR=  1.0000000000000000   ,ASQL= 0.0           ,  0.0               ,
 0.0              ,  0.0              ,  0.0              ,BI= 0.76000000000000000   ,B1= 0.0                      ,B2=
 0.0              ,B3= 0.0            ,CNI=  10.667000000000000   ,CNIX= 0.0               ,  0.0                    ,
 0.0              ,  0.0              ,  0.0              ,CSTR= 0.0                      ,CTANK=  0.29999999999999990-01,
CTRET= 0.11111111111111111   ,DI=  13.000000000000000   ,DMRETR= 0.0              ,DPOW= 0.0             ,ECI=
 0.75000000000000000-01,ECIX= 0.0          ,  0.0              ,  0.0              ,  0.0
 0.0              ,EI= 0.0            ,EMUDDD= 0.0                       ,EMUDDX= 0.0
 0.0              ,  0.0              ,  0.0              ,  0.0                       ,GAMMAX=  1.0000000000000000   ,GAP=
 0.99999999999999990-04,HOUR=  6.5230000000000000   ,OMI=  80.513748000000000   ,OMIX= 0.0
 0.0              ,  0.0              ,  0.0              ,  0.0                       ,POWFIX= -1.0000000000000000   ,
FSIGN=  1.0000000000000000   ,RADDDD=  1.0000000000000000   ,RADDDX= 0.0          ,  0.0
 0.0              ,  0.0              ,  0.0              ,RAP=  38.000000000000000   ,REVS= 0.0              ,
RPER=  2.0000000000000000   ,SAI=  2.7675000000000000   ,SAIX= 0.0               ,  0.0
 0.0              ,  0.0              ,  0.0              ,SOI=  71.852918200000000   ,SOIX= 0.0             ,
 0.0              ,  0.0              ,  0.0              ,  0.0                       ,SPIRET=  300.00000000000000   ,
STATE=  1.0000000000000000   ,  0.0          ,  0.0              ,  0.0                 ,  1.0000000000000000   ,
 0.0              ,STEP1= 0.31250000000000000-01,STEP2= 0.12500000000000000   ,TCOAST= 0.0
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,TDV= -1.0000000000000000   ,TGO=
-1.0000000000000000   ,THRET=  400.00000000000000   ,TOFF= -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   ,
-1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   ,
-1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   ,
-1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   , -1.0000000000000000   ,
-1.0000000000000000   , -1.0000000000000000   ,TPI= 0.0           ,TPIX= 0.0                 ,  0.0                  ,
 0.0              ,  0.0              ,  0.0              ,TPOWER= 0.10000000000000000D 31,TSCALE=
 1.0000000000000000   ,T2=  50.000000000000000   ,  100.00000000000000   ,  150.00000000000000   ,  200.00000000000000   ,
 250.00000000000000   ,  300.00000000000000   ,  350.00000000000000   ,  400.00000000000000   ,  450.00000000000000   ,
 500.00000000000000   ,XANG1= 0.0           ,XANG2= 0.0                 ,XSWING= 0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  0.0              ,  0.0              ,
 0.0              ,  0.0              ,  0.0              ,  1.0000015000000000   ,X0=  1.0000000000000000   ,
 0.0              ,IBAL=          0,INTPR=          0,IOUT=          0,IRK=          1,IRL=          1,IROT=          0,ISPIN=
        0,ITF=          3,ITPRNT=          0,JPP=          0,JPRINT=          0,JT=          0,KPART=          0,LAUNCH=
        0,LOADX=          0,MAXHAM=          5,MBOOST=         10,MDAY=         19,MODE=          4,MONTH=         11,MOPT=
        0,MOPTX=          0,          0,          0,          0,MOPT2=          3,MOPT3=         11,MOPT4=          0,
        0,          0,          0,          0,          0,          0,          0,          0,MPOW=          0,
MPRINT=          0,MPUNCH=          0,MREAD=          0,MSWING=          0,          0,          0,          0,
        0,          0,          0,          0,MTMASS=          3,MUPDAT=          0,MYEAR=       1976,NDIST=
        3,NHUNG=         25,NORMAL=          1,NPERF=          0,NPRINT=          3,NSET=          0,          0,        300,
        0,        300,NSWING=          0,NSWPAR=          1,NTAPE=         17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	2.2875000000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	2.2256756756756750D-03	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-8.5574324324324320D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	-3.8581081081081080D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	1.6334459459459460D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	2.9979729729729730D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	11	4.4870000000000000D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
8	12	3.1840000000000000D 04	2.0000000000000000D 03	9.9999999999999990D-04	1.0000000000000000D 00
9	13	1.5460000000000000D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00
10	15	-5.1000000000000000D 02	8.0000000000000000D 00	9.9999999999999990D-07	1.0000000000000000D 00
11	16	1.4490000000000000D 02	1.0000000000000000D 02	9.9999999999999990D-07	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	11	0.0	9.9999999999999990D-05
8	12	0.0	9.9999999999999990D-05
9	13	0.0	9.9999999999999990D-05
10	15	0.0	9.9999999999999990D-05
11	16	6.5500000000000000D 02	9.9999999999999990D-05

THIS CASE IS CONVERGED.

11 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 4 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			START OF TRAJECTORY, THRUST ON				
0.0	1.10851112D 00	8.31755538D-02	1.01037421D 00	9.59360607D 01	1.80000000D 02	1.01660569D 00	0.0
1.05135897D-01	-1.01115457D 00	0.0	1.02709186D 00	9.98584000D-02	-1.81989824D-02	1.00000000D 00	7.41059282D-02
2.28773375D 00	2.35238131D-03	-8.55586734D-01	-3.85933138D-01	1.68354917D 00	2.99898364D-01	1.00000000D 00	1.18757201D-01
0.0	0.0	0.0	7.55556884D 01	7.15384614D 01	1.04921026D 00	9.79106930D-01	1.50718323D 00
-1.95089569D 01	8.41604143D 01	8.44967357D 01	0.0	-8.40639393D 01	3.82904893D-01	1.03209505D 00	0.0
			SWITCH THRUST OFF				
1.17313959D 02	1.59260171D 00	3.34127517D-01	2.03682664D 00	8.65299814D 01	2.95162955D 02	1.30814972D 00	1.05764446D 02
1.21475744D 00	4.83579543D-01	-4.20816677D-02	-8.28803809D-02	9.45557866D-01	4.97756304D-03	8.75380529D-01	5.92569205D-02
1.23953184D-01	8.41563827D-01	5.73597839D-01	-7.66377587D-01	-4.48453137D-01	7.02308941D-01	1.25317444D 00	1.18757139D-01
-1.28164894D 00	-1.33035614D-01	0.0	9.35481125D 01	1.14513936D 02	1.18945421D 00	6.85351130D-01	0.0
3.41606829D 01	6.13029959D 01	6.65685862D 01	-1.84346555D 00	2.17068748D 01	1.66783456D 01	9.49196293D-01	1.17313959D 02
			SWITCH THRUST ON				
1.25514487D 02	1.59260171D 00	3.34127517D-01	2.03682664D 00	8.65299814D 01	3.00619456D 02	1.34698434D 00	1.11220948D 02
1.19784177D 00	6.14690598D-01	-4.11591505D-02	-1.55710076D-01	9.12465407D-01	7.49171847D-03	8.75380529D-01	5.66714110D-02
2.00638334D-02	7.76769519D-01	6.70293472D-01	-7.08047361D-01	-4.68934991D-01	6.62628079D-01	1.25317444D 00	1.18757139D-01
-1.28164894D 00	-1.33035814D-01	0.0	9.47781756D 01	1.21114380D 02	1.18945421D 00	6.55447756D-01	0.0
4.05804159D 01	6.31214232D 01	6.59491372D 01	-1.75273430D 00	2.71653120D 01	1.74573041D 01	9.25686163D-01	1.17313959D 02
INPUT TARGET			END OF TRAJECTORY, THRUST ON				
6.55000000D 02	2.76749999D 00	7.58599957D-02	1.06070000D 01	8.05137479D 01	1.07762621D 02	2.59220231D 00	2.72158716D 02
-2.52300020D 00	-3.80094832D-01	4.54403989D-01	6.26575929D-02	-6.36632907D-01	-3.12301759D-02	6.75359154D-01	2.42665137D-02
2.61009734D 00	-6.53367554D 00	-1.22706435D 00	1.64039170D 00	-2.54129341D-01	-6.41565530D-01	2.44430629D 00	1.18757172D-01
-8.59633697D 00	-4.34810434D-01	0.0	8.16589167D 01	9.65408204D 01	1.65878177D 00	2.16530636D-01	5.59770989D 00
-4.28807613D 00	1.04623826D 02	1.04581983D 02	1.00959130D 01	-1.71434721D 02	2.40146050D 00	6.40474645D-01	6.46799472D 02

```
CASE  1                                          ITERATOR SUMMARY

                                              INDEPENDENT PARAMETERS

  1.PRIM1( 2.2877338D 00)    2.PRIM2( 2.3923813D-03)    3.PRIM3(-8.5598873D-01)    4.PDOT1(-3.8593314D-01)    5.PDOT2( 1.6835492D 00)
  6.PDOT3( 2.9989836D-01)    7.LMASS( 1.0000000D 00)    8. LTAU( 0.0          )    9.     ( 0.0          )   10.DECLN( 0.0          )
 11.ACCEL( 4.4883520D-04)   12.V JET( 3.1840265D 04)   13.VINF1( 1.5467972D 03)   14.VINF2( 0.0          )   15.TIME1(-5.1002698D 02)
 16.TIME2( 1.4497302D 02)   17.IPARK( 0.0          )   18.VELO1( 0.0          )   19.VELO2( 0.0          )   20.VELO3( 0.0          )
 21.THET1( 0.0          )   22.THET2( 0.0          )   23.THET3( 0.0          )   24.THET4( 0.0          )   25.THET5( 0.0          )
 26.THET6( 0.0          )   27.THET7( 0.0          )   28.THET8( 0.0          )   29.THET9( 0.0          )   30.LDEGR( 0.0          )
 31. PHI1( 0.0          )   32. PHI2( 0.0          )   33. PHI3( 0.0          )   34. PHI4( 0.0          )   35. PHI5( 0.0          )
 36. PHI6( 0.0          )   37. PHI7( 0.0          )   38. PHI8( 0.0          )   39. PHI9( 0.0          )   40.PHI10( 0.0          )
 41.PR1-A( 0.0          )   42.PR2-A( 0.0          )   43.PR3-A( 0.0          )   44.PD1-A( 0.0          )   45.PD2-A( 0.0          )
 46.PD3-A( 0.0          )   47.VINFA( 0.0          )   48.TIMEA( 0.0          )   49.KSAMP( 0.0          )   50.KDROP( 0.0          )
 51.PR1-B( 0.0          )   52.PR2-B( 0.0          )   53.PR3-B( 0.0          )   54.PD1-B( 0.0          )   55.PD2-B( 0.0          )
 56.PD3-B( 0.0          )   57.VINFB( 0.0          )   58.TIMEB( 0.0          )   59.KSAMP( 0.0          )   60.KDROP( 0.0          )
 61.PR1-C( 0.0          )   62.PR2-C( 0.0          )   63.PR3-C( 0.0          )   64.PD1-C( 0.0          )   65.PD2-C( 0.0          )
 66.PD3-C( 0.0          )   67.VINFC( 0.0          )   68.TIMEC( 0.0          )   69.KSAMP( 0.0          )   70.KDROP( 0.0          )

                                              DEPENDENT PARAMETERS

  1.DELTA X(-1.18569D-08)    2.DELTA Y( 2.08840D-08)    3.DELTA Z( 3.81948D-09)    4.DELT XD(-5.64392D-09)    5.DELT YD( 2.06982D-09)
  6.DELT ZD( 9.07374D-10)    7.        ( 0.0        )    8.        ( 0.0        )    9.        ( 0.0        )   10.        ( 0.0        )
 11,T,ACCEL(-3.53754D-09)   12,T,V JET( 1.50456D-09)   13,T,VINF1(-2.14185D-09)   14.        ( 0.0        )   15,T,TIME1(-1.44349D-08)
 16.  TIME ( 6.55000D 02)   17.        ( 0.0        )   18.        ( 0.0        )   19.        ( 0.0        )   20.        ( 0.0        )
 21.       ( 0.0        )   22.        ( 0.0        )   23.        ( 0.0        )   24.        ( 0.0        )   25.        ( 0.0        )
 26.       ( 0.0        )   27.        ( 0.0        )   28.        ( 0.0        )   29.        ( 0.0        )   30.        ( 0.0        )
 31.       ( 0.0        )   32.        ( 0.0        )   33.        ( 0.0        )   34.        ( 0.0        )   35.        ( 0.0        )
 36.       ( 0.0        )   37.        ( 0.0        )   38.        ( 0.0        )   39.        ( 0.0        )   40.        ( 0.0        )
 41.       ( 0.0        )   42.        ( 0.0        )   43.        ( 0.0        )   44.        ( 0.0        )   45.        ( 0.0        )
 46.       ( 0.0        )   47.        ( 0.0        )   48.        ( 0.0        )   49.        ( 0.0        )   50.        ( 0.0        )
 51.       ( 0.0        )   52.        ( 0.0        )   53.        ( 0.0        )   54.        ( 0.0        )   55.        ( 0.0        )
 56.       ( 0.0        )   57.        ( 0.0        )   58.        ( 0.0        )   59.        ( 0.0        )   60.        ( 0.0        )
 61.       ( 0.0        )   62.        ( 0.0        )   63.        ( 0.0        )   64.        ( 0.0        )   65.        ( 0.0        )
 66.       ( 0.0        )   67.        ( 0.0        )   68.        ( 0.0        )   69.        ( 0.0        )   70.        ( 0.0        )

THRUST SWITCHING TIMES (DAYS)         0.0    ON     117.314  OFF    125.514  ON     655.000  ON

                                        ELECTRIC PROPULSION PARAMETERS
     POWER               EFFICIENCY           PROP TIME                J              PROP TIME RATIO         AVE ACCEL
   13.5349456587        0.6514104420       646.7994715256         6.8596080921         0.9874801092          0.0005461595

                                            MASS COMPONENT BREAKDOWN
     INITIAL             PROPULSION           PROPELLANT            TANKAGE              STRUCTURE             PAYLOAD
   1233.8933905803      338.3736424682       400.5721937759        12.0171658133          0.0                  482.9303685229


SWITCH-COUNT HISTORY    ALL 4

   151 THRUST COMPUTE STEPS,      1 COAST COMPUTE STEPS
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE	SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION		PSI		THRUST ANGLES THETA		PHI	INPUT POWER		ARRAY ANGLE
0	0.0	0.0	1.017		95.5		0.0	ON	1.51D 00		-19.5		84.2		84.5	13.3	ON	0.0
6	84.729	81.1	1.170	MAX	166.5		0.17		2.10D-01		8.1		61.7		62.0	10.9		0.0
5	92.038	87.0	1.198		165.2		0.20		1.33D-01		13.5		60.7	MIN	61.6	10.6		0.0
4	103.184	95.6	1.244		156.6		0.26		4.80D-02		22.5	MIN	60.1		62.6	10.0		0.0
4	117.314	105.8	1.308		148.7		0.35	OFF	0.0		34.2		61.3		66.6	9.3		0.0
5	121.360	108.5	1.327		145.9		0.38	MIN	-2.32D-03		*****		******		*****	0.0		90.0
5	125.514	111.2	1.347		143.0		0.41	ON	0.0		40.7		63.1		69.9	8.9		0.0
5	176.054	139.2	1.596		111.3		0.95		2.55D-01	MAX	58.0		91.7		90.9	6.8		0.0
5	300.042	184.1	2.108		46.6		2.67		1.24D 00		34.2	MAX	114.4		110.0	4.2		0.0
4	379.180	205.4	2.318		9.8		3.31		2.01D 00		19.3		113.2	MAX	111.8	3.6		0.0
4	395.989	209.7	2.352	MIN	9.3		3.36		2.19D 00		16.7		112.7		111.7	3.5		0.0
4	410.733	213.3	2.380		9.0	MAX	3.38		2.36D 00		14.6		112.4		111.6	3.4		0.0
4	634.714	267.6	2.583		163.2	MIN	1.61		5.31D 00		-3.6		105.4		105.3	2.9		0.0
5	635.379	267.8	2.583	MAX	163.3		1.61		5.32D 00		-3.6		105.3		105.3	2.9		0.0
4	655.000	272.6	2.592		151.7		1.67	ON	5.60D 00		-4.3		104.6		104.6	2.9	ON	0.0

MISSION SCHEDULE

JUNE 28, 1975 5.875469840 00 G.M.T.
2442591.745D 00 JULIAN DATE

DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	1.0513590D-01	-1.0111546D 00	0.0	9.7845267D-01	9.9808387D-02	0.0	1.0166057D 00	0.0	-84.064
S/C	1.0513590D-01	-1.0111546D 00	0.0	1.0270917D 00	9.9856400D-02	-1.8198982D-02	1.0166057D 00	0.0	-84.064

APRIL 13, 1977 5.875469840 00 G.M.T.
2443246.745D 00 JULIAN DATE

ARRIVE AT INPUT TARGET

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-2.5236002D 00	-3.8009455D-01	4.5440395D-01	6.2697598D-02	-6.3663291D-01	-3.1230177D-02	2.5922023D 00	10.096	-171.435
S/C	-2.5236002D 00	-3.8009453D-01	4.5440395D-01	6.2697593D-02	-6.3663291D-01	-3.1230176D-02	2.5922023D 00	10.096	-171.435

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND INPUT TARGET IS 272.5885 DEGREES.

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

EARTH TO INPUT TARGET WITH FIXED ARRIVAL EXCESS SPEED

ARRIVAL AT 144.973 DAYS AFTER INPUT TARGET PERIHELION

LAUNCH VEHICLE IS TITAN III B(CORE)/CENTAUR (COEFFICIENTS = 41836.9750 4499.6729 2293.2194)

LD = JUN 28, 1975, 5.8755 HOURS GMT
JULIAN DATE 42591.7448

AD = APR 13, 1977, 5.8755 HOURS GMT
JULIAN DATE 43246.7448

FLIGHT TIME = 655.0000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
12.5000	12.5000	0.0300	0.0	0.76000	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
1233.8934	338.3736	400.5722	12.0172	0.0	482.9304

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
13.5349	0.0	2.9307	0.553815	4.488352D-04	3246.803	0.65141	1.0000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
2.5922023	1.0166057	13.252155	0.54224390	646.79947	216.47167	272.15872

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-18.7301	28.5000	1546.79719	2.392582	0.00018	0.000000

CASE 2 TIME TO GO CPU 284, I/O 42 SEC

PROGRAM INPUTS

X 1 =	2.287500000000000D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 2 =	2.225675675675675D-03,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 3 =	-8.557432432432432D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 4 =	-3.858108108108108D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 5 =	1.683445945945946D 00,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 6 =	2.997972972972973D-01,	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X 7 =	1.000000000000000D 00,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X 8 =	0.0 ,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X 9 =	0.0 ,	0.0 ,	3.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X10 =	0.0 ,	0.0 ,	9.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X11 =	4.487000000000000D-04,	1.000000000000000D 00,	9.999999999999999D-04,	1.000000000000000D-11,	1.000000000000000D 00,
X12 =	3.184000000000000D 04,	1.000000000000000D 00,	2.000000000000000D 03,	9.999999999999999D-04,	1.000000000000000D 00,
X13 =	1.546000000000000D 03,	1.000000000000000D 00,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X14 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-04,	1.000000000000000D 00,
X15 =	-5.100000000000000D 02,	1.000000000000000D 00,	8.000000000000000D 00,	9.999999999999999D-07,	1.000000000000000D 00,
X16 =	1.449000000000000D 02,	1.000000000000000D 00,	1.000000000000000D 02,	9.999999999999999D-07,	1.000000000000000D 00,
X17 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X18 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X19 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X20 =	0.0 ,	0.0 ,	1.000000000000000D 00,	9.999999999999999D-05,	1.000000000000000D 00,
X21 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X22 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X23 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X24 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X25 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X26 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X27 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X28 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X29 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X30 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X31 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X32 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X33 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X34 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X35 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X36 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X37 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X38 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X39 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X40 =	0.0 ,	0.0 ,	1.000000000000000D 01,	9.999999999999999D-05,	1.000000000000000D 00,
X41 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X42 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X43 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X44 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X45 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X46 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X47 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X48 =	0.0 ,	0.0 ,	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X49 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X50 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X51 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X52 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X53 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X54 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X55 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X56 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X57 =	0.0 ,	0.0 ,	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X58 =	0.0 ,	0.0 ,	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X59 =	0.0 ,	0.0 ,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X60 =	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ORIGINAL PAGE IS OF POOR QUALITY

```
X61 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X62 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X63 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X64 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X65 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X66 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X67 = 0.0                     ,  0.0                     ,  5.0000000000000000D 02,  9.9999999999999999D-05,  1.0000000000000000D 00,
X68 = 0.0                     ,  0.0                     ,  5.0000000000000000D 01,  9.9999999999999999D-07,  1.0000000000000000D 00,
X69 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
X70 = 0.0                     ,  0.0                     ,  3.0000000000000000D 00,  1.0000000000000000D-08,  1.0000000000000000D 00,
Y 1 = 0.0                     ,  1.0000000000000000D 00,  9.9999999999999999D-05,
Y 2 = 0.0                     ,  1.0000000000000000D 00,  9.9999999999999999D-05,
Y 3 = 0.0                     ,  1.0000000000000000D 00,  9.9999999999999999D-05,
Y 4 = 0.0                     ,  1.0000000000000000D 00,  9.9999999999999999D-05,
Y 5 = 0.0                     ,  1.0000000000000000D 00,  9.9999999999999999D-05,
Y 6 = 0.0                     ,  1.0000000000000000D 00,  9.9999999999999999D-05,
Y 7 = 1.0000000000000000D 03,  3.0000000000000000D 00,  0.0                     ,
Y 8 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y 9 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y10 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y11 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y12 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y13 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y14 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y15 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y16 = 6.5500000000000000D 02,  3.0000000000000000D 00,  9.9999999999999999D-05,
Y17 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y18 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y19 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y20 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y21 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y22 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y23 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y24 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y25 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y26 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y27 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y28 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y29 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y30 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y31 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y32 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y33 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y34 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y35 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y36 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y37 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y38 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y39 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y40 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y41 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y42 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y43 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y44 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y45 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y46 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y47 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y48 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y49 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y50 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y51 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y52 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y53 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y54 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
Y55 = 0.0                     ,  0.0                     ,  9.9999999999999999D-05,
```

```
Y56 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y57 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y58 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y59 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y60 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y61 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y62 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y63 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y64 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y65 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y66 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y67 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y68 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y69 =  0.0              ,   0.0             ,   9.999999999999999D-05,
Y70 =  0.0              ,   0.0             ,   9.999999999999999D-05,
&OUTPUT
AAI= 0.0          ,AE= 0.0          ,ALPHAA=  12.50000000000000   ,ALPHAT=  12.50000000000000   ,ALTITU=
 0.0          ,AN=  1.500000000000000   ,AR=  1.000000000000000   ,ASDL= 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          ,BI= 0.7600000000000000   ,B1= 0.0          ,B2=
 0.0          ,B3= 0.0          ,CNI=  10.60700000000000   ,CNIX= 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          ,CSTR= 0.0          ,CTANK= 0.2999999999999999D-01,
CTRET= 0.1111111111111111   ,DI=  13.00000000000000   ,DMRETR= 0.0          ,DPOW= 0.0          ,ECI=
 0.7550000000000000D-01,ECIX= 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          ,EI= 0.0          ,EMUODD= 0.0          ,EMUODX= 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          ,GAMMAX=  1.000000000000000   ,GAP=
 0.9999999999999999D-04,HOUR=  6.523000000000000   ,ONI=  80.51374800000000   ,CMIX= 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          ,POWFIX= -1.000000000000000   ,
PSICN=  1.000000000000000   ,RADODC=  1.000000000000000   ,RADODX= 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          ,RAP=  38.00000000000000   ,REVS= 0.0          ,
RPER=  2.000000000000000   ,SAI=  2.767500000000000   ,SAIX= 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          ,SOI=  71.85291820000000   ,SOIX= 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          ,SPIRET=  300.0000000000000   ,
STATE= -2.523676030323941   ,-0.3792948522832918   , 0.4544431933486205   , 0.6251560407990260D-01,-0.6366602913326269   ,
-0.3119740570267966D-01,STEP1= 0.3125000000000000D-01,STEP2= 0.1250000000000000   ,TCOAST= 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          ,TDV= -1.000000000000000   ,TGO=
 -1.000000000000000   ,THRET=  400.0000000000000   ,TOFF= -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   ,TPI= 0.0          ,TPIX= 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          ,TPOWER= 0.1000000000000000D 31,TSCALE=
 1.000000000000000   ,T2=  50.00000000000000   ,  100.0000000000000   ,  150.0000000000000   ,  200.0000000000000   ,
 250.0000000000000   ,  300.0000000000000   ,  350.0000000000000   ,  400.0000000000000   ,  450.0000000000000   ,
 500.0000000000000   ,XANG1= 0.0          ,XANG2= 0.0          ,XSWING= 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          , 0.0          ,
 0.0          , 0.0          , 0.0          , 0.0          ,XO= 0.1051358965743675   ,
 -1.011154569394612   , 0.0          ,  1.027091661519134   , 0.9985840001317360D-01,-0.1819898239787017D-01,
 1.000000000000000   ,IBAL=      0,INTPR=      0,IOUT=      0,IRK=      1,IRL=      1,IROT=      0,ISPIN=
      0,ITF=      3,ITPRNT=      0,JPP=      0,JPRINT=      0,JT=      0,KPART=      0,LAUNCH=
      0,LOACX=      0,MAXHAM=      5,MBOOST=     10,MDAY=     19,MODE=      4,MONTH=     11,MOPT=
      0,MOPTX=      0,      0,      0,      0,      0,MOPT2=      3,MOPT3=     11,MOPT4=      0,
      0,      0,      0,      0,      0,      0,      0,MPOW=      0,
MPRINT=      0,MPUNCH=      0,MREAD=      0,MSWING=      0,      0,      0,      0,
      0,      0,      0,      0,MTMASS=      3,MUPDAT=      0,MYEAR=   1976,NDIST=
      3,NHUNG=     25,NORMAL=      1,NPERF=      7,NPRINT=      3,NSET=     11,     11,    300,
      0,    300,NSWING=      0,NSWPAR=      1,NTAPE=     17
&END
```

ORIGINAL PAGE IS
OF POOR QUALITY

CASE 2

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	2.2875000000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	2.2256756756756750D-03	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-8.5574324324324320D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	-3.8581081081081080D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	1.6834459459459460D 00	3.0000000000000000D 00	1.0000000000000000D-06	1.0000000000000000D 00
6	6	2.9979729729729730D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	11	4.4870000000000000D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
8	12	3.1840000000000000D 04	2.0000000000000000D 03	9.9999999999999990D-04	1.0000000000000000D 00
9	13	1.5460000000000000D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00
10	15	-5.1000000000000000D 02	6.0000000000000000D 00	9.9999999999999990D-07	1.0000000000000000D 00
11	16	1.4490000000000000D 02	1.0000000000000000D 02	9.9999999999999990D-07	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	7	1.0000000000000000D 03	0.0
8	16	6.5500000000000000D 02	9.9999999999999990D-05

ITERATOR IS NOW IN IMPROVE MODE.

THIS CASE IS CONVERGED.

117 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 33 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

CASE 2

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LC	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			START OF TRAJECTORY, THRUST ON				
0.0	1.10848517D 00	8.31554212D-02	1.01064324D 00	9.59170547D 01	1.80000000D 02	1.01660503D 00	0.0
1.04800935D-01	-1.01111886D 00	0.0	1.02711537D 00	9.95157089D-02	-1.82036685D-02	1.00000000D 00	7.40910073D-02
2.28722699D 00	1.53643303D-03	-8.56204247D-01	-3.85238440D-01	1.68345370D 00	2.99524676D-01	1.00000000D 00	1.18683092D-01
0.0	0.0	0.0	7.59964017D 01	7.15342852D 01	1.04919978D 00	9.79107748D-01	1.50688452D 00
-1.95175927D 01	6.41614898D 01	8.44580436D 01	0.0	-8.40829153D 01	3.83104724D-01	1.03208543D 00	0.0
			SWITCH THRUST OFF				
1.17326544D 02	1.59246477D 00	3.34055816D-01	2.03766737D 00	8.65492883D 01	2.95134581D 02	1.30813769D 00	1.05774343D 02
1.21462196D 00	4.83382542D-01	-4.21066319D-02	-8.27732217D-02	9.45546202D-01	4.96453296D-03	8.75405544D-01	5.92440727D-02
1.23864844D-01	3.41541164D-01	5.73795265D-01	-7.66390071D-01	-4.48170224D-01	7.02437453D-01	1.25310547D 00	1.18683030D-01
-1.20152452D 00	-1.32990448D-01	0.0	9.35470622D 01	1.14501620D 02	1.18943354D 00	6.85306683D-01	0.0
3.41530932D 01	6.13165276D 01	6.65570606D 01	-1.84465577D 00	2.16978082D 01	1.66756726D 01	9.49175260D-01	1.17326544D 02
			SWITCH THRUST ON				
1.25499035D 02	1.59246477D 00	3.34055816D-01	2.03766737D 00	8.65492883D 01	3.00572997D 02	1.34683143D 00	1.11212759D 02
1.19794593D 00	6.14052616D-01	-4.12312346D-02	-1.55373329D-01	9.12585750D-01	7.47230474D-03	8.75405544D-01	5.68562044D-02
2.05538105D-02	7.77011085D-01	6.65794051D-01	-7.08260753D-01	-4.68617865D-01	6.62904631D-01	1.25310547D 00	1.18683030D-01
-1.28152452D 00	-1.32990448D-01	0.0	9.47731954D 01	1.21081153D 02	1.18943354D 00	6.55561941D-01	-4.44089210D-16
4.06515916D 01	6.31281000D 01	6.55445061D 01	-1.76425889D 00	2.71381584D 01	1.74519665D 01	9.25748053D-01	1.17326544D 02
INPUT TARGET			END OF TRAJECTORY, THRUST ON				
6.53000000D 02	2.76718197D 00	7.58211621D-02	1.06065031D 01	8.05148147D 01	1.07756782D 02	2.59218558D 00	2.72172929D 02
-2.52361428D 00	-3.79877762D-01	4.54411784D-01	6.26362483D-02	-6.36510949D-01	-3.12157222D-02	6.75417466D-01	2.42597973D-02
2.60780231D 00	-6.53112142D 00	-1.22630929D 00	1.63951140D 00	-2.54026531D-01	-6.41453565D-01	2.44361137D 00	1.18683064D-01
-8.59575672D 00	-4.34642136D-01	0.0	8.16598603D 01	9.65416047D 01	1.65869643D 00	2.16533175D-01	5.59467730D 00
-4.28828751D 00	1.04618970D 02	1.04577136D 02	1.00961538D 01	-1.71439580D 02	2.40206351D 00	6.40446111D-01	6.46827509D 02

```
CASE  2                                   ITERATCR SUMMARY

                                       INDEPENDENT PARAMETERS

 1,PRIM1( 2.28722700D 00)   2,PRIM2( 1.63643300D-03)   3,PRIM3(-8.56204210D-01)   4,PDOT1(-3.85238440D-01)   5,PDOT2( 1.68345370 00)
 6,PDOT3( 2.99524680D-01)   7,LMASS( 1.00000000D 00)   8, LTAU( 0.0           )   9,      ( 0.0           )  10,DECLN( 0.0           )
11,ACCEL( 4.48744460D-04)  12,V JET( 3.18437020 04)  13,VINF1( 1.54655300D 03)  14,VINF2( 0.0           )  15,TIME1(-5.10046880 02)
16,TIME2( 1.44953120D 02)  17,IPARK( 0.0           )  18,VELO1( 0.0           )  19,VELO2( 0.0           )  20,VELO3( 0.0           )
21,THET1( 0.0           )  22,THET2( 0.0           )  23,THET3( 0.0           )  24,THET4( 0.0           )  25,THET5( 0.0           )
26,THET6( 0.0           )  27,THET7( 0.0           )  28,THET8( 0.0           )  29,THET9( 0.0           )  30,LDEGR( 0.0           )
31, PHI1( 0.0           )  32, PHI2( 0.0           )  33, PHI3( 0.0           )  34, PHI4( 0.0           )  35, PHI5( 0.0           )
36, PHI6( 0.0           )  37, PHI7( 0.0           )  38, PHI8( 0.0           )  39, PHI9( 0.0           )  40,PHI10( 0.0           )
41,PR1-A( 0.0           )  42,PR2-A( 0.0           )  43,PR3-A( 0.0           )  44,PD1-A( 0.0           )  45,PD2-A( 0.0           )
46,PD3-A( 0.0           )  47,VINFA( 0.0           )  48,TIMEA( 0.0           )  49,KSAMP( 0.0           )  50,KDROP( 0.0           )
51,PR1-B( 0.0           )  52,PR2-B( 0.0           )  53,PR3-B( 0.0           )  54,PD1-B( 0.0           )  55,PD2-B( 0.0           )
56,PD3-B( 0.0           )  57,VINFB( 0.0           )  58,TIMEB( 0.0           )  59,KSAMP( 0.0           )  60,KDROP( 0.0           )
61,PR1-C( 0.0           )  62,PR2-C( 0.0           )  63,PR3-C( 0.0           )  64,PD1-C( 0.0           )  65,PD2-C( 0.0           )
66,PD3-C( 0.0           )  67,VINFC( 0.0           )  68,TIMEC( 0.0           )  69,KSAMP( 0.0           )  70,KDROP( 0.0           )

                                       DEPENDENT PARAMETERS

 1,DELTA X( 7.38791D-06)   2,DELTA Y(-1.14500D-06)   3,DELTA Z(-2.89027D-06)   4,DELT XD(-1.17532D-05)   5,DELT YD( 2.94280D-05)
 6,DELT ZD( 5.52405D-06)   7,NETMASS( 4.83057D 02)   8,        ( 0.0       )   9,        ( 0.0       )  10,        ( 0.0       )
11,        ( 0.0       )  12,        ( 0.0       )  13,        ( 0.0       )  14,        ( 0.0       )  15,        ( 0.0       )
16,   TIME ( 6.55000D 02)  17,        ( 0.0       )  18,        ( 0.0       )  19,        ( 0.0       )  20,        ( 0.0       )
21,        ( 0.0       )  22,        ( 0.0       )  23,        ( 0.0       )  24,        ( 0.0       )  25,        ( 0.0       )
26,        ( 0.0       )  27,        ( 0.0       )  28,        ( 0.0       )  29,        ( 0.0       )  30,        ( 0.0       )
31,        ( 0.0       )  32,        ( 0.0       )  33,        ( 0.0       )  34,        ( 0.0       )  35,        ( 0.0       )
36,        ( 0.0       )  37,        ( 0.0       )  38,        ( 0.0       )  39,        ( 0.0       )  40,        ( 0.0       )
41,        ( 0.0       )  42,        ( 0.0       )  43,        ( 0.0       )  44,        ( 0.0       )  45,        ( 0.0       )
46,        ( 0.0       )  47,        ( 0.0       )  48,        ( 0.0       )  49,        ( 0.0       )  50,        ( 0.0       )
51,        ( 0.0       )  52,        ( 0.0       )  53,        ( 0.0       )  54,        ( 0.0       )  55,        ( 0.0       )
56,        ( 0.0       )  57,        ( 0.0       )  58,        ( 0.0       )  59,        ( 0.0       )  60,        ( 0.0       )
61,        ( 0.0       )  62,        ( 0.0       )  63,        ( 0.0       )  64,        ( 0.0       )  65,        ( 0.0       )
66,        ( 0.0       )  67,        ( 0.0       )  68,        ( 0.0       )  69,        ( 0.0       )  70,        ( 0.0       )

THRUST SWITCHING TIMES (DAYS)       0.0   ON    117.327  OFF    125.499  ON    655.000  ON

                                       ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME                J             PROP TIME RATIO        AVE ACCEL
   13.5335441464       0.6514305311      646.8275069332       6.8671337144        0.9875229144         0.0005460255

                                         MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT          TANKAGE             STRUCTURE            PAYLOAD
   1233.9199895918     338.3386036608      400.5066743226      12.0152662297        0.0                 483.0572453787

HUNT-0.0/

SWITCH-COUNT HISTORY   ALL 4

   151 THRUST COMPUTE STEPS,     1 COAST COMPUTE STEPS
```

CASE 2

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE	SOLAR DISTANCE	COMMUNICATION ANGLE	COMMUNICATION DISTANCE	SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER	ARRAY ANGLE
0	0.0	0.0	1.017	55.5	0.0	ON 1.51D 00	-19.5	84.2	84.5	13.3	ON 0.0
7	84.733	81.1	1.170	MAX 166.5	0.17	2.10D-01	8.1	61.7	62.0	10.9	0.0
5	92.045	87.0	1.198	165.2	0.20	1.33D-01	13.5	60.7	MIN 61.6	10.6	0.0
4	103.178	95.6	1.244	158.6	0.26	4.80D-02	22.5	MIN 60.1	62.6	10.0	0.0
4	117.327	105.8	1.308	146.7	0.35	OFF 0.0	34.2	61.3	66.6	9.3	0.0
5	121.359	108.5	1.327	145.5	0.38	MIN -2.31D-03	*****	******	*****	0.0	90.0
6	125.499	111.2	1.347	143.0	0.41	ON -4.44D-16	40.7	63.1	69.9	8.9	0.0
5	176.076	139.2	1.596	111.3	0.95	2.55D-01	MAX 58.0	91.7	90.9	6.8	0.0
5	300.083	184.1	2.108	46.6	2.67	1.24D 00	34.2	MAX 114.4	110.0	4.2	0.0
4	379.233	205.5	2.318	9.8	3.31	2.01D 00	19.3	113.1	MAX 111.8	3.6	0.0
4	396.009	209.7	2.352	MIN 5.3	3.36	2.19D 00	16.7	112.7	111.7	3.5	0.0
4	410.754	213.4	2.380	9.1	MAX 3.37	2.36D 00	14.6	112.3	111.6	3.4	0.0
4	634.733	267.7	2.583	163.3	MIN 1.61	5.31D 00	-3.6	105.4	105.3	2.9	0.0
5	635.399	267.8	2.583	MAX 162.2	1.61	5.32D 00	-3.6	105.3	105.3	2.9	0.0
4	655.000	272.6	2.592	151.7	1.67	ON 5.59D 00	-4.3	104.6	104.6	2.9	ON 0.0

MISSION SCHEDULE

JUNE 28, 1975 5.397875CCD 00 G.M.T.
2442591.725D 00 JULIAN DATE

DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	1.0480093D-01	-1.0111887D 00	0.0	9.7846688D-01	9.9478917D-02	0.0	1.0166050D 00	0.0	-84.083
S/C	1.0480093D-01	-1.0111887D 00	0.0	1.0271154D 00	9.9513709D-02	-1.8203669D-02	1.0166050D 00	0.0	-84.083

APRIL 13, 1977 5.357875210 00 G.M.T.
2443246.725D 00 JULIAN DATE

ARRIVE AT INPUT TARGET

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-2.5236216D 00	-3.7587662D-01	4.5441467D-01	6.2648001D-02	-6.3664038D-01	-3.1221246D-02	2.5921931D 00	10.096	-171.440
S/C	-2.5236143D 00	-3.7587776D-01	4.5441176D-01	6.2636248D-02	-6.3661095D-01	-3.1215722D-02	2.5921856D 00	10.096	-171.440

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND INPUT TARGET IS 272.6023 DEGREES.

CASE 2 (CCNVERGED) PERFCRMANCE SUMMARY

EARTH TO INPUT TARGET WITH FIXED ARRIVAL EXCESS SPEED

ARRIVAL AT 144.953 DAYS AFTER INPUT TARGET PERIHELION

LAUNCH VEHICLE IS TITAN III B(CORE)/CENTAUR (COEFFICIENTS = 41836.9750 4499.6729 2293.2194)

LD = JUN 28, 1975, 5.3979 HOURS GMT JULIAN DATE 42591.7249 AD = APR 13, 1977, 5.3979 HOURS GMT JULIAN DATE 43246.7249 FLIGHT TIME = 655.0000 DAYS.

ELECTRIC PROPULSICN SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
12.5000	12.5000	0.0300	0.0	0.76000	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
1233.9200	338.3386	400.5089	12.0153	0.0	483.0572

ELECTRIC PROPULSICN SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
13.5335	0.0	2.9205	0.553715	4.487445D-04	3247.154	0.65143	1.0000000) 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
2.5921856	1.0166050	13.250798	0.54214641	646.82751	216.50262	272.17293

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-18.7452	28.5000	1546.55302	2.391826	0.95806	0.000001

C. DEEP SPACE PROBE

The objective of this mission is to transfer a specified net spacecraft mass from the Earth to a heliocentric distance of 10 AU in minimum time. The case demonstrates the use of the two-dimensional, open-angle transfer end conditions. A constant power profile consistent with nuclear electric propulsion is assumed and the Titan III B (Core)/Centaur launch vehicle is employed. The velocity at the final distance is left unconstrained, and the travel angle, reference thrust acceleration, jet exhaust speed, and launch excess speed are optimized. Convergence is obtained after two iterations. The program inputs required for the case are listed below and are followed by the output resulting from using the default values of NPRINT and MPRINT.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0,X11(2)=1.D0,X7=1.D0
X12(2)=1.D0,X13(2)=1.D0,X16(2)=1.D0,Y1=1.D1,2.D0,Y2(2)=2.D0,Y4(2)=2.D0
Y5(2)=2.D0,Y7=4.D2,3.D0,Y11(2)=1.D0,Y12(2)=1.D0,Y13(2)=1.D0,LAUNCH=0
MBOOST=10,MOPT3=11,MODE=3,X1=-4.4319D-1,X2=2.35D0,X4=-2.8355D0
X5=4.4319D-1,X11=3.2516D-4,X12=4.385899D4,X13=1.82397D3,X16=1.1D3 &END
```

CASE 1 TIME TO GO CPU 29, I/O 13 SEC

PROGRAM INPUTS

X 1 =	-4.4319000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 =	2.8500000000000000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 =	-2.8355000000000000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 =	4.4319000000000000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 =	1.0000000000000000D 00,	0.0,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 =	0.0,	0.0,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 =	0.0,	0.0,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 =	0.0,	0.0,	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 =	3.2515999999999999D-04,	1.0000000000000000D 00,	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 =	4.3858990000000000D 04,	1.0000000000000000D 00,	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 =	1.8239700000000000D 03,	1.0000000000000000D 00,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 =	0.0,	0.0,	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 =	0.0,	0.0,	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 =	1.1000000000000000D 03,	1.0000000000000000D 00,	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 =	0.0,	0.0,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 =	0.0,	0.0,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 =	0.0,	0.0,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 =	0.0,	0.0,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 =	0.0,	0.0,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 =	0.0,	0.0,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 =	0.0,	0.0,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 =	0.0,	0.0,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X59 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X60 =	0.0,	0.0,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,

X61 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X62 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X63 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X64 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X65 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X66 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X67 =	0.0	0.0	5.0000000000000000D 02	9.9999999999999999D-05	1.0000000000000000D 00
X68 =	0.0	0.0	5.0000000000000000D 01	9.9999999999999999D-07	1.0000000000000000D 00
X69 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X70 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
Y 1 =	1.0000000000000000D 01	2.0000000000000000D 00	9.9999999999999999D-05		
Y 2 =	0.0	2.0000000000000000D 00	9.9999999999999999D-05		
Y 3 =	0.0	0.0	9.9999999999999999D-05		
Y 4 =	0.0	2.0000000000000000D 00	9.9999999999999999D-05		
Y 5 =	0.0	2.0000000000000000D 00	9.9999999999999999D-05		
Y 6 =	0.0	0.0	9.9999999999999999D-05		
Y 7 =	4.0000000000000000D 02	3.0000000000000000D 00	9.9999999999999999D-05		
Y 8 =	0.0	0.0	9.9999999999999999D-05		
Y 9 =	0.0	0.0	9.9999999999999999D-05		
Y10 =	0.0	0.0	9.9999999999999999D-05		
Y11 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y12 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y13 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y14 =	0.0	0.0	9.9999999999999999D-05		
Y15 =	0.0	0.0	9.9999999999999999D-05		
Y16 =	0.0	0.0	9.9999999999999999D-05		
Y17 =	0.0	0.0	9.9999999999999999D-05		
Y18 =	0.0	0.0	9.9999999999999999D-05		
Y19 =	0.0	0.0	9.9999999999999999D-05		
Y20 =	0.0	0.0	9.9999999999999999D-05		
Y21 =	0.0	0.0	9.9999999999999999D-05		
Y22 =	0.0	0.0	9.9999999999999999D-05		
Y23 =	0.0	0.0	9.9999999999999999D-05		
Y24 =	0.0	0.0	9.9999999999999999D-05		
Y25 =	0.0	0.0	9.9999999999999999D-05		
Y26 =	0.0	0.0	9.9999999999999999D-05		
Y27 =	0.0	0.0	9.9999999999999999D-05		
Y28 =	0.0	0.0	9.9999999999999999D-05		
Y29 =	0.0	0.0	9.9999999999999999D-05		
Y30 =	0.0	0.0	9.9999999999999999D-05		
Y31 =	0.0	0.0	9.9999999999999999D-05		
Y32 =	0.0	0.0	9.9999999999999999D-05		
Y33 =	0.0	0.0	9.9999999999999999D-05		
Y34 =	0.0	0.0	9.9999999999999999D-05		
Y35 =	0.0	0.0	9.9999999999999999D-05		
Y36 =	0.0	0.0	9.9999999999999999D-05		
Y37 =	0.0	0.0	9.9999999999999999D-05		
Y38 =	0.0	0.0	9.9999999999999999D-05		
Y39 =	0.0	0.0	9.9999999999999999D-05		
Y40 =	0.0	0.0	9.9999999999999999D-05		
Y41 =	0.0	0.0	9.9999999999999999D-05		
Y42 =	0.0	0.0	9.9999999999999999D-05		
Y43 =	0.0	0.0	9.9999999999999999D-05		
Y44 =	0.0	0.0	9.9999999999999999D-05		
Y45 =	0.0	0.0	9.9999999999999999D-05		
Y46 =	0.0	0.0	9.9999999999999999D-05		
Y47 =	0.0	0.0	9.9999999999999999D-05		
Y48 =	0.0	0.0	9.9999999999999999D-05		
Y49 =	0.0	0.0	9.9999999999999999D-05		
Y50 =	0.0	0.0	9.9999999999999999D-05		
Y51 =	0.0	0.0	9.9999999999999999D-05		
Y52 =	0.0	0.0	9.9999999999999999D-05		
Y53 =	0.0	0.0	9.9999999999999999D-05		
Y54 =	0.0	0.0	9.9999999999999999D-05		
Y55 =	0.0	0.0	9.9999999999999999D-05		
Y56 =	0.0	0.0	9.9999999999999999D-05		
[illegible]	[illegible]	[illegible]	[illegible]		

ORIGINAL PAGE IS OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

```
Y57 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y58 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y59 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y60 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y61 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y62 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y63 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y64 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y65 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y66 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y67 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y68 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y69 =  0.0                  .  0.0              .  9.999999999999999D-05,
Y70 =  0.0                  .  0.0              .  9.999999999999999D-05,
&OUTPUT
AAI= 0.0                 ,AE= 0.0                 ,ALPHAA=  15.0000000000000    ,ALPHAT=  15.0000000000000   ,ALTITU=
 0.0                ,AN=  1.50000000000000    ,AR=  1.00000000000000    ,ASOL= 0.0                  , 0.0              ,
 0.0                , 0.0                 , 0.0                 ,BI= 0.760000000000000    ,B1= 0.0                  ,B2=
 0.0                ,B3= 0.0                  ,CNI= 0.0                   ,CNIX= 0.0                   , 0.0        ,
 0.0                , 0.0                 , 0.0                 ,CSTR= 0.0                  ,CTANK= 0.2999999999999999D-01,
CTRET= 0.111111111111111    ,DI=  13.0000000000000    ,DWRETR= 0.0                       ,DPOW= 0.0                ,ECI=
 0.0                ,ECIX= 0.0                , 0.0                      , 0.0              , 0.0              ,
 0.0                ,EI= 0.0                  ,EMUDDD= 0.0                  ,EMUDDX= 0.0                      ,
 0.0                , 0.0                 , 0.0                 , 0.0                 ,GAMMAX=  1.00000000000000    ,GAP=
 0.9999999999999999D-04,HOUR=  12.0000000000000     ,OMI= 0.0                ,OMIX= 0.0                       ,
 0.0                , 0.0                 , 0.0                 , 0.0                 ,POWFIX= -1.00000000000000    ,
PSIGN=  1.00000000000000    ,RADDDD=  1.00000000000000    ,RADDDX= 0.0                       , 0.0                 ,
 0.0                , 0.0                 , 0.0                 ,RAP=  38.0000000000000    ,REVS= 0.0                  ,
RPER=  2.00000000000000     ,SAI=  1.00000000000000     ,SAIX= 0.0                 , 0.0                  ,
 0.0                , 0.0                 , 0.0                 ,SOI= 0.0                 ,SOIX= 0.0                ,
 0.0                , 0.0                 , 0.0                 , 0.0                 ,SPIRET=  300.000000000000    ,
STATE=  1.00000000000000     , 0.0                , 0.0                 , 0.0                  , 1.00000000000000    ,
 0.0                ,STEP1= 0.3125000000000000D-01,STEP2= 0.125000000000000    ,TCOAST= 0.0                  ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 ,TDV= -1.00000000000000    ,TGO=
 -1.00000000000000  ,THRET=  400.000000000000     ,TOFF= -1.00000000000000     , -1.00000000000000    , -1.00000000000000    ,
 -1.00000000000000  , -1.00000000000000   , -1.00000000000000   , -1.00000000000000   , -1.00000000000000   ,
 -1.00000000000000  , -1.00000000000000   , -1.00000000000000   , -1.00000000000000   , -1.00000000000000   ,
 -1.00000000000000  , -1.00000000000000   , -1.00000000000000   , -1.00000000000000   , -1.00000000000000   ,
 -1.00000000000000  , -1.00000000000000   ,TPI= 0.0                 ,TPIX= 0.0                 , 0.0          ,
 0.0                , 0.0                 , 0.0                 ,TPOWER= 0.1000000000000000D 31,TSCALE=
 1.00000000000000   ,T2=  50.0000000000000    , 100.000000000000     , 150.000000000000    , 200.000000000000    ,
 250.000000000000   , 300.000000000000    , 350.000000000000    , 400.000000000000    , 450.000000000000    ,
 500.000000000000   ,XANG1= 0.0                  ,XANG2= 0.0                       ,XSWING= 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                , 0.0                 , 0.0                 , 0.0                 ,X0=  1.00000000000000    ,
 0.0                , 0.0                 , 0.0                 , 1.00000150000000    , 0.0                 ,
 0.0                ,IBAL=          0,INTPR=          0,IDJT=          0,IRK=          1,IRL=          1,IROT=          0,ISPIN=
        0,ITF=          3,ITPRNT=          0,JPP=          0,JPRINT=          0,JT=          0,KPART=          0,LAUNCH=
        0,LOADX=          0,MAXHAM=          5,MBOOST=          10,MDAY=          1,MODE=          3,MONTH=          1,MOPT=
        0,MOPTX=          0,          0,          0,          0,          0,MOPT2=          0,MOPT3=          11,MOPT4=          0,
        0,          0,          0,          0,          0,          0,          0,MPOW=          0,
MPRINT=          0,MPUNCH=          0,MREAD=          0,MSWING=          0,          0,          0,          0,
        0,          0,          0,          0,          0,MTMASS=          0,MUPDAT=          1,MYEAR=          1975,NDIST=
        3,NMUNG=          25,NORMAL=          0,NPERF=          0,NPRINT=          7,NSET=          0,          0,          300,
        0,          300,NSWING=          0,NSWPAR=          1,NTAPE=          17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	-4.43190000000000000D-01	3.00000000000000000D 00	1.00000000000000000D-08	1.00000000000000000D 00
2	2	2.85000000000000000D 00	3.00000000000000000D 00	1.00000000000000000D-08	1.00000000000000000D 00
3	4	-2.83550000000000000D 00	3.00000000000000000D 00	1.00000000000000000D-08	1.00000000000000000D 00
4	5	4.43190000000000000D-01	3.00000000000000000D 00	1.00000000000000000D-08	1.00000000000000000D 00
5	11	3.25159999999999990D-04	9.99999999999999990D-04	1.00000000000000000D-11	1.00000000000000000D 00
6	12	4.38589900000000000D 04	2.00000000000000000D 03	9.99999999999999990D-04	1.00000000000000000D 00
7	13	1.82397000000000000D 03	5.00000000000000000D 02	9.99999999999999990D-05	1.00000000000000000D 00
8	16	1.10000000000000000D 03	1.00000000000000000D 02	9.99999999999999990D-07	1.00000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	1.00000000000000000D 01	9.99999999999999990D-05
2	2	0.0	9.99999999999999990D-05
3	4	0.0	9.99999999999999990D-05
4	5	0.0	9.99999999999999990D-05
5	7	4.00000000000000000D 02	9.99999999999999990D-05
6	11	0.0	9.99999999999999990D-05
7	12	0.0	9.99999999999999990D-05
8	13	0.0	9.99999999999999990D-05

```
---------- NOMINAL TRAJECTORY  1 (TOTAL   1) ---------- INHIBITOR IS   5.8208D-11 ----------
                                   INDEPENDENT PARAMETERS
 1.PRIM1(-4.4319000D-01)   2.PRIM2( 2.8500000D 00)   4.PDOT1(-2.8355000D 00)   5.PDOT2( 4.4319000D-01)  11.ACCEL( 3.2516000D-04)
12.V JET( 4.3858990D 04)  13.VINF1( 1.8239700D 03)  16.TIME2( 1.1000000D 03)
                                    DEPENDENT PARAMETERS
 1. RADIUS( 9.994600D 00)   2.T.ANGLE( 3.668870D-04)   4.T.PRIM1(-3.13330D-04)   5.T.PRIM2(-1.247210D-03)   7.NETMASS( 4.01859D 02)
11.T.ACCEL( 5.042120D-03)  12.T.V JET(-3.271040D-02)  13.T.VINF1( 4.672640D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON     544.518  OFF    1100.000  OFF
                                 ELECTRIC PROPULSION PARAMETERS
     POWER               EFFICIENCY           PROP TIME               J                PROP TIME RATIO         AVE ACCEL
   12.2602846471         0.6986221329      544.5178664969        7.6383442528         0.4950162423          0.0004029366
                                   MASS COMPONENT BREAKDOWN
     INITIAL             PROPULSION           PROPELLANT            TANKAGE              STRUCTURE              PAYLOAD
  1201.2050464296      367.8085394123      418.9686363639       12.5690590909           0.0                401.8588115625

---------- NOMINAL TRAJECTORY  2 (TOTAL   4) ---------- INHIBITOR IS   2.2737D-13 ----------
                                   INDEPENDENT PARAMETERS
 1.PRIM1(-4.4784593D-01)   2.PRIM2( 2.8464367D 00)   4.PDOT1(-2.8249945D 00)   5.PDOT2( 4.4782552D-01)  11.ACCEL( 3.2857137D-04)
12.V JET( 4.2722344D 04)  13.VINF1( 1.8224702D 03)  16.TIME2( 1.0963399D 03)
                                    DEPENDENT PARAMETERS
 1. RADIUS( 9.995470D 00)   2.T.ANGLE( 3.038890D-04)   4.T.PRIM1(-5.67877D-04)   5.T.PRIM2( 3.690290D-04)   7.NETMASS( 4.00105D 02)
11.T.ACCEL(-4.186540D-05)  12.T.V JET(-7.191010D-05)  13.T.VINF1( 5.451420D-05)
THRUST SWITCHING TIMES (DAYS)        0.0    ON     532.214  OFF    1096.340  OFF
                                 ELECTRIC PROPULSION PARAMETERS
     POWER               EFFICIENCY           PROP TIME               J                PROP TIME RATIO         AVE ACCEL
   12.1223090381         0.6955931780      532.2143674291        7.5805571855         0.4854464797          0.0004086921
                                   MASS COMPONENT BREAKDOWN
     INITIAL             PROPULSION           PROPELLANT            TANKAGE              STRUCTURE              PAYLOAD
  1201.3951499876      363.6692711435      424.8746790464       12.7462403714           0.0                400.1049594262

THIS CASE IS CONVERGED.

    5 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND   2 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.
```

ORIGINAL PAGE IS
OF POOR QUALITY

CASE 1

SWITCH POINT SUMMARY

TIME R1 L1 LG PSI	SEMI-MAJOR AXIS R2 L2 LC THETA	ECCENTRICITY R3 L3 LPHI PHI	INCLINATION V1 L4 CONE LATITUDE	NODE V2 L5 CLOCK LONGITUDE	ARG PJS V3 L6 HMAG FLT PTH ANG_E	RMAG MASS RATIO L7 POWER FNCT VMAG	TRAVEL THRUST ACC HAM SWITCH FNCT PROP TIME
EARTH			START OF TRAJECTORY, THRUST ON				
0.0	1.14238863D 00	1.24958096D-01	0.0	1.80000000D 02	1.80000000D 02	1.00000000D 00	0.0
1.00000000D 00	0.0	0.0	-9.50657196D-03	1.06044838D 00	0.0	1.00000000D 00	5.54043079D-02
-4.47715911D-01	2.84677076D 00	0.0	-2.82540756D 00	4.47716501D-01	0.0	1.00000000D 00	6.71149223D-02
0.0	0.0	0.0	8.64876941D 01	7.62683085D 01	1.06044838D 00	1.00000000D 00	2.18465308D 00
0.0	9.89377831D 01	9.89377831D 01	0.0	0.0	-5.13624108D-01	1.06049099D 00	0.0
			SWITCH THRUST OFF				
5.32403711D 02	-6.35564471D 00	1.29933652D 00	0.0	1.80000000D 02	5.52055729D 01	4.25087450D 00	2.35205573D 02
-2.42569223D 00	-3.49083819D 00	0.0	4.96362145D-02	-7.90802201D-01	0.0	6.46274146D-01	8.57288015D-02
-2.12716220D-01	-1.26070692D 00	0.0	5.13454340D-02	1.69036982D-01	0.0	2.83786814D 00	6.71148386D-02
-1.50537174D 01	-4.82888926D-01	0.0	8.08157958D 01	1.00831334D 02	2.09151474D 00	1.00000000D 00	2.22044605D-16
0.0	2.52172447D 01	2.52172447D 01	0.0	-1.24794427D 02	5.16140052D 01	7.92358426D-01	5.32403711D 02
INPUT TARGET			END OF TRAJECTORY, THRUST OFF				
1.09660177D 03	-6.35564471D 00	1.29933652D 00	0.0	1.80000000D 02	8.21427729D 01	1.00000014D 01	2.62142773D 02
-1.36705084D 00	-9.90611929D 00	0.0	1.30633529D-01	-5.83331213D-01	0.0	6.46274146D-01	8.57288015D-02
-9.07715287D-08	-1.17031355D-07	0.0	1.63839223D-02	1.18723511D-01	0.0	2.83786814D 00	6.71148386D-02
-1.50537174D 01	-4.82888926D-01	0.0	7.69188815D 01	2.75483373D 02	2.09151474D 00	1.00000000D 00	-1.27852640D 00
0.0	-2.99405429D 01	2.99405429D 01	0.0	-9.78572271D 01	6.95199909D 01	5.97779577D-01	5.32403711D 02

```
CASE  1                                      ITERATOR SUMMARY

                                          INDEPENDENT PARAMETERS

  1.PRIM1(-4.47715910-01)   2.PRIM2( 2.84677080 00)   3.PRIM3( 0.0            )   4.PDOT1(-2.82540770 00)   5.PDOT2( 4.47716500-01)
  6.PDOT3( 0.0          )   7.LMASS( 1.0000000D 00)   8. LTAU( 0.0            )   9.      ( 0.0          )  10.DECLN( 0.0            )
 11.ACCEL( 3.2855465D-04)  12.V JET( 4.27263340 04)  13.VINF1( 1.8225352D 03)  14.VINF2( 0.0            )  15.TIME1( 0.0            )
 16.TIME2( 1.09660180 03)  17.IPARK( 0.0          )  18.VELO1( 0.0            )  19.VELO2( 0.0            )  20.VELO3( 0.0            )
 21.THET1( 0.0          )  22.THET2( 0.0          )  23.THET3( 0.0            )  24.THET4( 0.0            )  25.THET5( 0.0            )
 26.THET6( 0.0          )  27.THET7( 0.0          )  28.THET8( 0.0            )  29.THET9( 0.0            )  30.LDEGR( 0.0            )
 31. PHI1( 0.0          )  32. PHI2( 0.0          )  33. PHI3( 0.0            )  34. PHI4( 0.0            )  35. PHI5( 0.0            )
 36. PHI6( 0.0          )  37. PHI7( 0.0          )  38. PHI8( 0.0            )  39. PHI9( 0.0            )  40.PHI10( 0.0            )
 41.PR1-A( 0.0          )  42.PR2-A( 0.0          )  43.PR3-A( 0.0            )  44.PD1-A( 0.0            )  45.PD2-A( 0.0            )
 46.PD3-A( 0.0          )  47.VINFA( 0.0          )  48.TIMEA( 0.0            )  49.KSAMP( 0.0            )  50.KDROP( 0.0            )
 51.PR1-B( 0.0          )  52.PR2-B( 0.0          )  53.PR3-B( 0.0            )  54.PD1-B( 0.0            )  55.PD2-B( 0.0            )
 56.PD3-B( 0.0          )  57.VINFB( 0.0          )  58.TIMEB( 0.0            )  59.KSAMP( 0.0            )  60.KDROP( 0.0            )
 61.PR1-C( 0.0          )  62.PR2-C( 0.0          )  63.PR3-C( 0.0            )  64.PD1-C( 0.0            )  65.PD2-C( 0.0            )
 66.PD3-C( 0.0          )  67.VINFC( 0.0          )  68.TIMEC( 0.0            )  69.KSAMP( 0.0            )  70.KDROP( 0.0            )

                                           DEPENDENT PARAMETERS

  1. RADIUS( 1.000000D 01)  2.T.ANGLE(-1.556900-08)   3.          ( 0.0        )   4.T.PRIM1(-9.077150-08)   5.T.PRIM2(-1.170310-07)
  6.       ( 0.0        )   7.NETMASS( 4.00000D 02)   8.          ( 0.0        )   9.        ( 0.0        )  10.        ( 0.0        )
 11.T.ACCEL(-4.425330-08)  12.T.V JET( 3.95433D-08)  13.T.VINF1(-3.343620-08)  14.        ( 0.0        )  15.        ( 0.0        )
 16.       ( 0.0        )  17.        ( 0.0        )  18.          ( 0.0        )  19.        ( 0.0        )  20.        ( 0.0        )
 21.       ( 0.0        )  22.        ( 0.0        )  23.          ( 0.0        )  24.        ( 0.0        )  25.        ( 0.0        )
 26.       ( 0.0        )  27.        ( 0.0        )  28.          ( 0.0        )  29.        ( 0.0        )  30.        ( 0.0        )
 31.       ( 0.0        )  32.        ( 0.0        )  33.          ( 0.0        )  34.        ( 0.0        )  35.        ( 0.0        )
 36.       ( 0.0        )  37.        ( 0.0        )  38.          ( 0.0        )  39.        ( 0.0        )  40.        ( 0.0        )
 41.       ( 0.0        )  42.        ( 0.0        )  43.          ( 0.0        )  44.        ( 0.0        )  45.        ( 0.0        )
 46.       ( 0.0        )  47.        ( 0.0        )  48.          ( 0.0        )  49.        ( 0.0        )  50.        ( 0.0        )
 51.       ( 0.0        )  52.        ( 0.0        )  53.          ( 0.0        )  54.        ( 0.0        )  55.        ( 0.0        )
 56.       ( 0.0        )  57.        ( 0.0        )  58.          ( 0.0        )  59.        ( 0.0        )  60.        ( 0.0        )
 61.       ( 0.0        )  62.        ( 0.0        )  63.          ( 0.0        )  64.        ( 0.0        )  65.        ( 0.0        )
 66.       ( 0.0        )  67.        ( 0.0        )  68.          ( 0.0        )  69.        ( 0.0        )  70.        ( 0.0        )

THRUST SWITCHING TIMES (DAYS)       0.0    ON     532.404  OFF    1096.602  OFF

                                        ELECTRIC PROPULSION PARAMETERS
      POWER               EFFICIENCY          PROP TIME             J                PROP TIME RATIO         AVE ACCEL
      12.1225495053       0.6956041876        532.4037110895        7.6833970415       0.4855032391          0.0004086949

                                          MASS COMPONENT BREAKDOWN
      INITIAL             PROPULSION          PROPELLANT            TANKAGE            STRUCTURE             PAYLOAD
     1201.3869106294      363.6764851597      424.9616114367        12.7488483431      0.0                   399.9999656898

SWITCH-COUNT HISTORY   ALL 3

   127 THRUST COMPUTE STEPS.    12 COAST COMPUTE STEPS
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THETA	PHI	INPUT POWER	ARRAY ANGLE
0	0.0	0.0		1.000		81.1		0.0	ON	2.13D 00	0.0	98.9	98.9	12.1	0.0
4	4.563	4.8	MIN	1.000		85.5		0.00		2.25D 00	0.0	98.4	98.4	12.1	0.0
4	78.760	79.4		1.124		164.4		0.13	MAX	2.81D 00	0.0	85.0	85.0	12.1	0.0
5	92.595	91.3		1.173	MAX	180.0		0.17		2.79D 00	0.0	82.4	82.4	12.1	0.0
5	401.746	216.0		3.039	MIN	0.0		4.04		5.03D-01	0.0	39.8	39.8	12.1	0.0
5	460.291	225.8		3.539		37.9	MAX	4.27		2.43D-01	0.0	32.8	32.8	12.1	0.0
4	532.404	235.2		4.251		96.0		4.03	OFF	2.22D-16	0.0	25.2	25.2	12.1	0.0
5	573.284	239.4		4.688		137.3	MIN	3.90		-1.19D-01	*****	******	*****	0.0	0.0
8	611.538	242.7		5.095	MAX	180.0		4.10		-2.23D-01	*****	******	*****	0.0	0.0
5	805.322	253.7		7.115	MIN	0.0		8.11		-5.70D-01	*****	******	*****	0.0	0.0
6	849.707	255.4		7.566		37.4	MAX	8.34		-7.55D-01	*****	******	*****	0.0	0.0
6	960.521	258.9		8.673		143.9	MIN	7.84		-9.97D-01	*****	******	*****	0.0	0.0
6	994.104	259.8		9.004	MAX	180.0		8.00		-1.07D 00	*****	******	*****	0.0	0.0
4	1096.602	262.1		10.000		75.8		10.20	OFF	-1.28D 00	*****	******	*****	0.0	0.0

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

ORBIT TO ORBIT FLYBY

LAUNCH VEHICLE IS TITAN III B(CORE)/CENTAUR (COEFFICIENTS = 41836.9750 4499.6729 2293.2194)

FLIGHT TIME = 1096.6018

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.0000	0.0300	0.0	0.76000	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
1201.3869	363.6765	424.9615	12.7488	0.0	400.0000

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
12.1225	0.0	12.1225	0.394721	3.2855470-04	4356.874	0.69560	1.0000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
10.0000014	0.9996217	12.122550	0.39472126	532.40371	532.40371	262.14277

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
0.0	28.5000	1822.53524	3.321635	16981.61963	288.375405

D. JUPITER FLYBY WITH BALLISTIC SWINGBY CONTINUATION

The objective of this mission is to place maximum payload on a flyby trajectory past Jupiter and to calculate for that optimum flyby trajectory the four appropriate sets of Jupiter flyby conditions which would result in ballistic continuation trajectories to Saturn, to Uranus, to Neptune and to Pluto. In addition to the ballistic-swingby-continuation feature, this case demonstrates the use of the launch-vehicle-independent option, which is invoked by setting POWFIX to a positive number, the value of which is the reference power, p_{ref}, of the spacecraft, in kilowatts. The specific case presented here is a 550 day Earth-to-Jupiter transfer with a launch excess speed of 4 km/sec and with a reference power of 15 kilowatts. In addition, two constraints are imposed on the solution: (1) the thrust cone-angle ϕ is constrained to be constant over the thrust period and (2) the propulsion time is constrained to be 200 days. The parameters

```
&INPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X7=1.D0,X8(2)=1.D0,X11(2)=1.D0,X15(2)=1.D0,X16(2)=1.D0
X21(2)=1.D0,Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=2.D0,Y5(2)=2.D0
Y6(2)=2.D0,Y8=2.D2,2.D0,Y11(2)=1.D0,Y15(2)=1.D0,Y16=5.5D2,3.D0
Y21(2)=1.D0,NOPT2=3,NOPT3=5,NOPT4=6,7,8,9,T2=6.D2,2.D3,4.D3,10.D3
NSWING=-1,NPRINT=3,MYEAR=1980,MONTH=11,MDAY=4,POWFIX=15.D0,X1(3)=1.D1
X2(3)=1.D1,X3(3)=1.D1,X4(3)=1.D1,X5(3)=1.D1,X6(3)=1.D1,X1=-8.2046D1
X2=6.5775318D1,X3=1.2496584 7D-1,X4=-6.70284300D1,X5=-2.11446761D1
X6=4.5355507D0,X11=6.5734576 7D-4,X12=2.941995D4,X13=4.D3
X15=-4.1198677 5D0,X16=5.4538013 2D2,X21=6.7464723D1 &END
```

optimized for this case include the reference thrust acceleration, the thrust cone-angle, and the launch date. The velocity at Jupiter arrival is left open. This particular case required 6 iterations to converge. The inputs for the case are listed above and the program output resulting from setting NPRINT = 3 and MPRINT = 0 is displayed on the following pages. The pertinent ballistic swingby-continuation trajectory data are displayed on the pages following the PERFORMANCE SUMMARY page.

CASE 1 TIME TO GO CPU 59, I/O 13 SEC

PROGRAM INPUTS

X 1 =	-8.2046000000000000D 01	1.0000000000000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
X 2 =	6.5775318500000000D 01	1.0000000000000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
X 3 =	1.2496584700000000D-01	1.0000000000000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
X 4 =	-6.7028480900000000D 01	1.0000000000000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
X 5 =	-2.1144676100000000D 01	1.0000000000000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
X 6 =	4.5855507600000000D 00	1.0000000000000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
X 7 =	1.0000000000000000D 00	0.0	3.0000000000000000D 00	9.9999999999999999D-07	1.0000000000000000D 00
X 8 =	0.0	1.0000000000000000D 00	3.0000000000000000D 00	9.9999999999999999D-07	1.0000000000000000D 00
X 9 =	0.0	0.0	3.0000000000000000D 00	9.9999999999999999D-07	1.0000000000000000D 00
X10 =	0.0	0.0	9.0000000000000000D 01	9.9999999999999999D-07	1.0000000000000000D 00
X11 =	6.5734576659999999D-04	1.0000000000000000D 00	9.9999999999999999D-04	1.0000000000000000D-11	1.0000000000000000D 00
X12 =	2.9419950000000000D 04	0.0	2.0000000000000000D 03	9.9999999999999999D-04	1.0000000000000000D 00
X13 =	4.0000000000000000D 03	0.0	5.0000000000000000D 02	9.9999999999999999D-05	1.0000000000000000D 00
X14 =	0.0	0.0	5.0000000000000000D 02	9.9999999999999999D-04	1.0000000000000000D 00
X15 =	-4.1198677500000000D 00	1.0000000000000000D 00	8.0000000000000000D 00	9.9999999999999999D-07	1.0000000000000000D 00
X16 =	5.4588013200000000D 02	1.0000000000000000D 00	1.0000000000000000D 02	9.9999999999999999D-07	1.0000000000000000D 00
X17 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X18 =	0.0	0.0	1.0000000000000000D 00	9.9999999999999999D-05	1.0000000000000000D 00
X19 =	0.0	0.0	1.0000000000000000D 00	9.9999999999999999D-05	1.0000000000000000D 00
X20 =	0.0	0.0	1.0000000000000000D 00	9.9999999999999999D-05	1.0000000000000000D 00
X21 =	6.7464728300000000D 01	1.0000000000000000D 00	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X22 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X23 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X24 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X25 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X26 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X27 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X28 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X29 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X30 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X31 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X32 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X33 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X34 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X35 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X36 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X37 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X38 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X39 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X40 =	0.0	0.0	1.0000000000000000D 01	9.9999999999999999D-05	1.0000000000000000D 00
X41 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X42 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X43 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X44 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X45 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X46 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X47 =	0.0	0.0	5.0000000000000000D 02	9.9999999999999999D-05	1.0000000000000000D 00
X48 =	0.0	0.0	5.0000000000000000D 01	9.9999999999999999D-07	1.0000000000000000D 00
X49 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X50 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X51 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X52 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X53 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X54 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X55 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X56 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X57 =	0.0	0.0	5.0000000000000000D 02	9.9999999999999999D-05	1.0000000000000000D 00
X58 =	0.0	0.0	5.0000000000000000D 01	9.9999999999999999D-07	1.0000000000000000D 00
X59 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00

X60 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X61 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X62 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X63 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X64 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X65 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X66 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-09,	1.0000000000000000D 00,
X67 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X68 =	0.0	0.0	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X69 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X70 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
Y 1 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 2 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 3 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 4 =	0.0	2.0000000000000000D 00,	9.9999999999999999D-05,		
Y 5 =	0.0	2.0000000000000000D 00,	9.9999999999999999D-05,		
Y 6 =	0.0	2.0000000000000000D 00,	9.9999999999999999D-05,		
Y 7 =	0.0	0.0	9.9999999999999999D-05,		
Y 8 =	2.0000000000000000D 02,	2.0000000000000000D 00,	9.9999999999999999D-05,		
Y 9 =	0.0	0.0	9.9999999999999999D-05,		
Y10 =	0.0	0.0	9.9999999999999999D-05,		
Y11 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y12 =	0.0	0.0	9.9999999999999999D-05,		
Y13 =	0.0	0.0	9.9999999999999999D-05,		
Y14 =	0.0	0.0	9.9999999999999999D-05,		
Y15 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y16 =	5.5000000000000000D 02,	3.0000000000000000D 00,	9.9999999999999999D-05,		
Y17 =	0.0	0.0	9.9999999999999999D-05,		
Y18 =	0.0	0.0	9.9999999999999999D-05,		
Y19 =	0.0	0.0	9.9999999999999999D-05,		
Y20 =	0.0	0.0	9.9999999999999999D-05,		
Y21 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y22 =	0.0	0.0	9.9999999999999999D-05,		
Y23 =	0.0	0.0	9.9999999999999999D-05,		
Y24 =	0.0	0.0	9.9999999999999999D-05,		
Y25 =	0.0	0.0	9.9999999999999999D-05,		
Y26 =	0.0	0.0	9.9999999999999999D-05,		
Y27 =	0.0	0.0	9.9999999999999999D-05,		
Y28 =	0.0	0.0	9.9999999999999999D-05,		
Y29 =	0.0	0.0	9.9999999999999999D-05,		
Y30 =	0.0	0.0	9.9999999999999999D-05,		
Y31 =	0.0	0.0	9.9999999999999999D-05,		
Y32 =	0.0	0.0	9.9999999999999999D-05,		
Y33 =	0.0	0.0	9.9999999999999999D-05,		
Y34 =	0.0	0.0	9.9999999999999999D-05,		
Y35 =	0.0	0.0	9.9999999999999999D-05,		
Y36 =	0.0	0.0	9.9999999999999999D-05,		
Y37 =	0.0	0.0	9.9999999999999999D-05,		
Y38 =	0.0	0.0	9.9999999999999999D-05,		
Y39 =	0.0	0.0	9.9999999999999999D-05,		
Y40 =	0.0	0.0	9.9999999999999999D-05,		
Y41 =	0.0	0.0	9.9999999999999999D-05,		
Y42 =	0.0	0.0	9.9999999999999999D-05,		
Y43 =	0.0	0.0	9.9999999999999999D-05,		
Y44 =	0.0	0.0	9.9999999999999999D-05,		
Y45 =	0.0	0.0	9.9999999999999999D-05,		
Y46 =	0.0	0.0	9.9999999999999999D-05,		
Y47 =	0.0	0.0	9.9999999999999999D-05,		
Y48 =	0.0	0.0	9.9999999999999999D-05,		
Y49 =	0.0	0.0	9.9999999999999999D-05,		
Y50 =	0.0	0.0	9.9999999999999999D-05,		
Y51 =	0.0	0.0	9.9999999999999999D-05,		
Y52 =	0.0	0.0	9.9999999999999999D-05,		
Y53 =	0.0	0.0	9.9999999999999999D-05,		
Y54 =	0.0	0.0	9.9999999999999999D-05,		
Y55 =	0.0	0.0	9.9999999999999999D-05,		
Y56 =	0.0	0.0	9.9999999999999999D-05,		

ORIGINAL PAGE IS OF POOR QUALITY

```
Y56 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y57 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y58 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y59 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y60 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y61 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y62 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y63 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y64 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y65 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y66 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y67 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y68 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y69 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
Y70 =  0.0             ,   0.0              ,   9.9999999999999990D-05,
&OUTPUT
AAI= 0.0                 ,AE= 0.0                        ,ALPHAA=  15.000000000000000     ,ALPHAT=  15.000000000000000     ,ALTITU=
 0.0                 ,AN=  1.5000000000000000     ,AR=  1.0000000000000000          ,ASOL= 0.0                      , 0.0
 0.0                 , 0.0                        , 0.0                      ,BI= 0.7600000000000000     ,B1= 0.0                  ,B2=
 0.0                 ,B3= 0.0                          ,CNI= 0.0                     ,CNIX= 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      ,CSTR= 0.0                        ,CTANK= 0.29999999999999990D-01,
CTRET= 0.1111111111111111     ,DI =  13.000000000000000       ,DMRETR= 0.0                      ,DPOW= 0.0                 ,ECI=
 0.0                 ,ECIX= 0.0                      , 0.0                      , 0.0                       , 0.0
 0.0                 ,EI= 0.0                        ,EMUODD= 0.0                         ,EMUODX= 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       ,GAMMAX=  1.0000000000000000    ,GAP=
 0.9999999999999990-04,HOUR=  12.000000000000000      ,OMI= 0.0                       ,OMIX= 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       ,POWFIX=  15.000000000000000
PSIGN=  1.0000000000000000     ,RADODD=  1.0000000000000000       ,RADODX= 0.0                      , 0.0
 0.0                 , 0.0                        , 0.0                      ,RAP=  38.000000000000000       ,REVS= 0.0
RPER =  2.3000000000000000     ,SAI=  1.0000000000000000        ,SAIX= 0.0                        , 0.0
 0.0                 , 0.0                        , 0.0                      ,SOI= 0.0                        ,SOIX= 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       ,SPIRET=  300.00000000000000
STATE=  1.0000000000000000     , 0.0                       , 0.0                      , 0.0                        , 1.0000000000000000
 0.0                 ,STEP1= 0.31250000000000000D-01,STEP2= 0.1250000000000000      ,TCOAST= 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       ,TDV= -1.0000000000000000     ,TSO=
-1.0000000000000000  ,THRET=  400.00000000000000      ,TOFF= -1.0000000000000000     , -1.0000000000000000     , -1.0000000000000000
-1.0000000000000000  , -1.0000000000000000       , -1.0000000000000000     , -1.0000000000000000     , -1.0000000000000000
-1.0000000000000000  , -1.0000000000000000       , -1.0000000000000000     , -1.0000000000000000     , -1.0000000000000000
-1.0000000000000000  , -1.0000000000000000       , -1.0000000000000000     , -1.0000000000000000     , -1.0000000000000000
-1.0000000000000000  , -1.0000000000000000       ,TPI= 0.0                  ,TPIX= 0.0                    , 0.0
 0.0                 , 0.0                        , 0.0                      ,TPOWER= 0.10000000000000000D 31,TSCALE=
 1.0000000000000000  ,T2=  600.00000000000000     ,  2000.0000000000000      ,  4000.0000000000000       ,  10000.000000000000
 250.00000000000000  ,  300.00000000000000       ,  350.00000000000000      ,  400.00000000000000       ,  450.00000000000000
 500.00000000000000  ,XANG1= 0.0                        ,XANG2= 0.0                       ,XSWING= 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       , 0.0
 0.0                 , 0.0                        , 0.0                      , 0.0                       ,XO=  1.0000000000000000
 0.0                 , 0.0                        , 0.0                      ,  1.0000001500000000       , 0.0
 0.0                 ,IBAL=            0,INTPR=            0,IOUT=            0,IRK=            1,IRL=            1,IROT=            0,ISPIN=
          0,ITF=            3,ITPRNT=            0,JPP=            0,JPRINT=            0,JT=            0,KPART=            0,LAUNCH=
          0,LOADX=            0,MAXHAM=            5,MBOOST=            0,MDAY=            4,MODE=            4,MONTH=           11,MOPT=
          0,MOPTX=            0,            0,            0,            0,            0,MOPT2=            3,MOPT3=            5,MOPT4=            6,
          7,            8,            9,            0,            0,            0,            0,MPOW=            0,
MPRINT=            0,MPUNCH=            0,MREAD=            0,MSWING=            0,            0,            0,            0,            0,
          0,            0,            0,            0,MTMASS=            0,MUPDAT=            1,MYEAR=         1980,NDIST=
          3,NHUNG=           25,NORMAL=            0,NPERF=            0,NPRINT=            3,NSET=            0,            0,          300,
          0,          300,NSWING=           -1,NSWPAR=            1,NTAPE=           17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	-8.2046000000000000D 01	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
2	2	6.5775318500000000D 01	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
3	3	1.2496584700000000D-01	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
4	4	-6.7028480900000000D 01	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
5	5	-2.1144676100000000D 01	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
6	6	4.5855507600000000D 00	1.0000000000000000D 01	1.0000000000000000D-08	1.0000000000000000D 00
7	8	0.0	3.0000000000000000D 00	9.9999999999999990D-07	1.0000000000000000D 00
8	11	6.5734576699999990D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
9	15	-4.1198677500000000D 00	8.0000000000000000D 00	9.9999999999999990D-07	1.0000000000000000D 00
10	16	5.4588013200000000D 02	1.0000000000000000D 02	9.9999999999999990D-07	1.0000000000000000D 00
11	21	6.7464728300000000D 01	1.0000000000000000D 01	9.9999999999999990D-05	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	8	2.0000000000000000D 02	9.9999999999999990D-05
8	11	0.0	9.9999999999999990D-05
9	15	0.0	9.9999999999999990D-05
10	16	5.5000000000000000D 02	9.9999999999999990D-05
11	21	0.0	9.9999999999999990D-05

ORIGINAL PAGE IS
OF POOR QUALITY

THIS CASE IS CONVERGED.

17 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 6 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			START OF TRAJECTORY, THRUST ON				
0.0	1.391067840 00	2.897535000D-01	3.328106C9D-02	4.03521364D 01	-2.54444375D-14	9.920015080-01	0.0
7.559839800-01	6.423046110-01	0.0	-7.736948760-01	8.35852599D-01	6.609890070-04	1.000000000D 00	1.197908320-01
-8.696306360 01	6.123345780 01	5.234891910-01	-6.614662460 01	-2.20740681D 01	7.294802970 00	1.000000000 00	3.805303170 00
0.0	0.0	0.0	9.612631900 01	7.749466490 01	1.128839150 00	1.010224800 00	7.914265310 01
2.439447550-01	7.100244350 01	7.100262230 01	0.0	4.035213640 01	-2.436306010 00	1.138970490 00	0.0
			SWITCH THRUST OFF				
2.000000000 02	9.584200430 00	8.733939210-01	1.23967938D 00	1.44876096D 02	3.29345477D 01	2.399705520 00	1.374540460 02
-2.397778120 00	9.192372380-02	2.822634600-02	-6.016931550-01	-6.055831560-01	1.820982500-02	7.428478930-01	3.972864190-02
-5.521616720 01	-3.300731620 01	8.441668950 00	1.704507670 01	4.806325180 00	-9.465413150-01	3.43333334C 01	3.805302820 00
-2.066518510 02	-4.535604190 00	1.134996400-10	9.337580510 01	1.161209920 02	1.507716810 00	2.488846180-01	8.881784200-14
1.086550370 01	.7.064214130 01	7.100262230 01	6.739526070-01	1.778045240 02	4.262380500 01	8.538718930-01	2.000000000 02
JUPITER			END OF TRAJECTORY, THRUST OFF				
5.500000000 02	9.584200430 00	8.733939210-01	1.239679380 00	1.44876096D 02	7.123569720 01	5.434471070 00	1.757551960 02
-4.387645530 00	-3.201889250 00	1.113246300-01	-1.855041730-01	-4.787010060-01	1.078235220-02	7.428478930-01	8.372368350-03
-1.795472220-09	3.168591390-09	-3.532794330-10	7.185594700 00	5.130510410 00	-1.517714160 00	3.433333340 01	3.805302820 00
-2.066518510 02	-4.535604190 00	1.134996400-10	8.368629970 01	2.886746860 02	1.507716810 00	5.244965850-02	-1.480451950 02
-4.767682340 00	-7.093411870 01	7.100262230 01	1.173780770 00	-1.438922920 02	5.729706300 01	5.135004480-01	2.000000000 02

```
CASE  1                                      ITERATOR SUMMARY

                                          INDEPENDENT PARAMETERS

  1,PRIM1(-8.69630640D 01)   2,PRIM2( 6.12334580D 01)   3,PRIM3( 5.2348919D-01)   4,PDOT1(-6.6146625D 01)   5,PDOT2(-2.2074068D 01)
  6,PDOT3( 7.29489300D 00)   7,LMASS( 1.0000000D 00)    8, LTAU(-1.0233073D 00)   9,      ( 0.0          )  10,DECLN( 0.0           )
 11,ACCEL( 7.03185060D-04)  12,V JET( 2.9419950D 04)   13,VINF1( 4.0000000D 03)  14,VINF2( 0.0           )  15,TIME1(-1.8806998D 00)
 16,TIME2( 5.48119300D 02)  17,IPARK( 0.0          )   18,VELO1( 0.0          )  19,VELO2( 0.0           )  20,VELO3( 0.0           )
 21,THET1( 7.10026220D 01)  22,THET2( 0.0          )   23,THET3( 0.0          )  24,THET4( 0.0           )  25,THET5( 0.0           )
 26,THET6( 0.0          )   27,THET7( 0.0          )   28,THET8( 0.0          )  29,THET9( 0.0           )  30,LDEGR( 0.0           )
 31, PHI1( 0.0          )   32, PHI2( 0.0          )   33, PHI3( 0.0          )  34, PHI4( 0.0           )  35, PHI5( 0.0           )
 36, PHI6( 0.0          )   37, PHI7( 0.0          )   38, PHI8( 0.0          )  39, PHI9( 0.0           )  40,PHI10( 0.0           )
 41,PR1-A( 0.0          )   42,PR2-A( 0.0          )   43,PR3-A( 0.0          )  44,PD1-A( 0.0           )  45,PD2-A( 0.0           )
 46,PD3-A( 0.0          )   47,VINFA( 0.0          )   48,TIMEA( 0.0          )  49,KSAMP( 0.0           )  50,KDROP( 0.0           )
 51,PR1-B( 0.0          )   52,PR2-B( 0.0          )   53,PR3-B( 0.0          )  54,PD1-B( 0.0           )  55,PD2-B( 0.0           )
 56,PD3-B( 0.0          )   57,VINFB( 0.0          )   58,TIMEB( 0.0          )  59,KSAMP( 0.0           )  60,KDROP( 0.0           )
 61,PR1-C( 0.0          )   62,PR2-C( 0.0          )   63,PR3-C( 0.0          )  64,PD1-C( 0.0           )  65,PD2-C( 0.0           )
 66,PD3-C( 0.0          )   67,VINFC( 0.0          )   68,TIMEC( 0.0          )  69,KSAMP( 0.0           )  70,KDROP( 0.0           )

                                          DEPENDENT PARAMETERS

  1,DELTA X( 3.635400D-11)   2,DELTA Y(-6.57496D-11)   3,DELTA Z( 3.82902D-12)   4,T,PRIM1(-1.79547D-09)   5,T,PRIM2( 3.16859D-09)
  6,T,PRIM3(-3.53279D-10)   7,        ( 0.0        )   8,   TAU ( 2.00000D 02)   9,        ( 0.0        )  10,        ( 0.0        )
 11,T,ACCEL(-1.10312D-12)  12,        ( 0.0        )  13,        ( 0.0        )  14,        ( 0.0        )  15,T,TIME1( 2.20813D-10)
 16,  TIME ( 5.50000D 02)  17,        ( 0.0        )  18,        ( 0.0        )  19,        ( 0.0        )  20,        ( 0.0        )
 21,T,THET1( 1.13509D-10)  22,        ( 0.0        )  23,        ( 0.0        )  24,        ( 0.0        )  25,        ( 0.0        )
 26,        ( 0.0        )  27,        ( 0.0        )  28,        ( 0.0        )  29,        ( 0.0        )  30,        ( 0.0        )
 31,        ( 0.0        )  32,        ( 0.0        )  33,        ( 0.0        )  34,        ( 0.0        )  35,        ( 0.0        )
 36,        ( 0.0        )  37,        ( 0.0        )  38,        ( 0.0        )  39,        ( 0.0        )  40,        ( 0.0        )
 41,        ( 0.0        )  42,        ( 0.0        )  43,        ( 0.0        )  44,        ( 0.0        )  45,        ( 0.0        )
 46,        ( 0.0        )  47,        ( 0.0        )  48,        ( 0.0        )  49,        ( 0.0        )  50,        ( 0.0        )
 51,        ( 0.0        )  52,        ( 0.0        )  53,        ( 0.0        )  54,        ( 0.0        )  55,        ( 0.0        )
 56,        ( 0.0        )  57,        ( 0.0        )  58,        ( 0.0        )  59,        ( 0.0        )  60,        ( 0.0        )
 61,        ( 0.0        )  62,        ( 0.0        )  63,        ( 0.0        )  64,        ( 0.0        )  65,        ( 0.0        )
 66,        ( 0.0        )  67,        ( 0.0        )  68,        ( 0.0        )  69,        ( 0.0        )  70,        ( 0.0        )

THRUST SWITCHING TIMES (DAYS)       0.0    ON     200.000  OFF     550.000  OFF

                                    ELECTRIC PROPULSION PARAMETERS
    POWER             EFFICIENCY        PROP TIME             J            PROP TIME RATIO       AVE ACCEL
    15.0000000000     0.6358474180      200.0000000036        7.1614632408     0.3636363636      0.0008158676

                                      MASS COMPONENT BREAKDOWN
    INITIAL           PROPULSION        PROPELLANT         TANKAGE             STRUCTURE          PAYLOAD
   922.0672384865    450.0000000000     237.1115334338       7.1133460030       0.0              227.8423590497

SWITCH-COUNT HISTORY   4.3.3.3.3.3/

   64 THRUST COMPUTE STEPS,    13 COAST COMPUTE STEPS
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE	SOLAR DISTANCE	COMMUNICATION ANGLE	COMMUNICATION DISTANCE	SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER	ARRAY ANGLE
9	0.0	0.0	0.992	75.5	0.0	ON 7.910 01	0.2	71.0	71.0	15.2	ON 0.0
4	8.015	9.2	MIN 0.989	85.2	0.02	8.690 01	0.7	71.0	71.0	MAX 15.2	0.0
4	37.751	43.2	1.041	119.6	0.11	MAX 1.000 02	2.1	71.0	71.0	14.2	0.0
4	86.639	87.9	1.335	MAX 179.3	0.35	7.680 01	4.2	70.9	71.0	10.0	0.0
4	200.000	137.5	2.409	92.4	2.13	OFF 8.880-14	10.9	70.6	71.0	3.7	0.0
5	346.365	161.2	3.784	MIN 0.8	4.78	-6.730 01	*****	******	*****	0.0	90.0
5	388.781	165.2	4.153	31.4	MAX 4.96	-8.430 01	*****	******	*****	0.0	90.0
5	515.840	174.0	5.177	153.0	MIN 4.27	-1.340 02	*****	******	*****	0.0	90.0
7	539.505	175.2	5.356	MAX 178.6	4.35	-1.440 02	*****	******	*****	0.0	90.0
5	550.000	175.8	5.434	168.1	4.44	OFF -1.480 02	*****	******	*****	0.0	ON 90.0

MISSION SCHEDULE

NOVEMBER 2, 1980 1.486322245D 01 G.M.T.
2444546.1190 00 JULIAN DATE — DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	7.5598398D-01	6.4239461D-01	0.0	-6.6389007D-01	7.5853554D-01	0.0	9.9200151D-01	0.0	40.352
S/C	7.5598398D-01	6.4239461D-01	0.0	-7.7369488D-01	8.3585260D-01	6.6098901D-04	9.9200151D-01	0.0	40.352

MAY 6, 1982 1.486320450D 01 G.M.T.
2445096.1190 00 JULIAN DATE — PASS JUPITER AT 13.773 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-4.3896455D 00	-3.2018893D 00	1.1132463D-01	2.5341940D-01	-3.3401799D-01	-4.3199164D-03	5.4344711D 00	1.174	-143.892
S/C	-4.3896455D 00	-3.2018893D 00	1.1132463D-01	-1.8550417D-01	-4.7870101D-01	1.0782352D-02	5.4344711D 00	1.174	-143.892

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND JUPITER IS 175.5965 DEGREES.

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

EARTH TO JUPITER FLYBY

LAUNCH VEHICLE INDEPENDENT MODE

LD = NOV 2, 1983, 14.8632 HOURS GMT
JULIAN DATE 44546.1193

AD = MAY 6, 1982, 14.8632 HOURS GMT
JULIAN DATE 45096.1193

FLIGHT TIME = 550.0000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.0000	0.0300	0.0	0.76000	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
922.0672	450.0000	237.1115	7.1133	0.0	227.8424

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
15.0000	0.0	0.7867	0.648384	7.0318510-04	3000.000	0.63585	1.0000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
5.4344711	0.9885940	15.219181	0.65785816	200.00000	109.97300	175.75520

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
13.5104	28.5000	4000.00000	16.000000	13772.59044	189.684247

FIXED THRUST ANGLE = 71.0026

SWINGBY CONTINUATION ANALYSIS

THIS CASE IS CONVERGED.

32 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 13 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

JUPITER SWINGBY CONTINUATION TO SATURN

PASS DIST (RADII)	SPEED (M/SEC)	INCLIN (DEG)	NODE (DEG)	ARG PER (DEG)	LEG TIME (DAYS)	MISSION TIME (DAYS)	ARR VINF (M/SEC)
87.5738	15201.78	175.2475	84.4245	319.401	1111.94	1661.94	6979.69

```
ARRIVAL   VOO = -4.389235720D-01 -1.446830200D-01  1.510226860D-02   MAG = 4.624015110D-01  (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO = -4.584161730D-01 -5.611819620D-02  2.281683080D-02   MAG = 4.624016080D-01  (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL   VOO = -9.492260770D-01 -3.128547830D-01  3.266050870D-02   MAG = 1.000000000D 00  (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO = -9.913810090D-01 -1.213624590D-01  4.934418550D-02   MAG = 1.000000000D 00  (ECLIPTIC REFERENCE SYSTEM)
```

HELIOCENTRIC APPROACH ANGLE = 17.9. DEPART ANGLE = 29.2. BEND ANGLE = 11.3 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC = -5.4 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED = 0.0 METERS/SECOND. BEND ANGLE = 11.3 DEGREES. (PLANETOCENTRIC)

THIS CASE IS CONVERGED.

22 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 9 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

JUPITER SWINGBY CONTINUATION TO URANUS

PASS DIST (RADII)	SPEED (M/SEC)	INCLIN (DEG)	NODE (DEG)	ARG PER (DEG)	LEG TIME (DAYS)	MISSION TIME (DAYS)	ARR VINF (M/SEC)
23.7111	18510.16	3.4004	295.7620	31.680	1713.90	2263.90	13150.67

```
ARRIVAL   VOO = -4.389235720D-01 -1.446830200D-01  1.510226860D-02   MAG = 4.624015110D-01  (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO = -2.872034030D-01 -3.623910890D-01  1.432871980D-03   MAG = 4.624015030D-01  (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL   VOO = -9.492260770D-01 -3.128547830D-01  3.266050870D-02   MAG = 1.000000000D 00  (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO = -6.211126080D-01 -7.837152070D-01  3.098761510D-03   MAG = 1.000000000D 00  (ECLIPTIC REFERENCE SYSTEM)
```

HELIOCENTRIC APPROACH ANGLE = 17.9. DEPART ANGLE = 15.5. BEND ANGLE = 33.4 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC = 3.1 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED = 0.0 METERS/SECOND. BEND ANGLE = 33.4 DEGREES. (PLANETOCENTRIC)

```
THIS CASE IS CONVERGED.

    78 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND  35 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

                                JUPITER     SWINGBY CONTINUATION TO      NEPTUNE

PASS DIST (RADII)  SPEED (M/SEC)  INCLIN (DEG)  NODE (DEG)  ARG PER (DEG)   LEG TIME (DAYS)  MISSION TIME (DAYS)  ARR VINF (M/SEC)
    11.1150          22714.46        4.4022      352.5703      345.824         2648.70            3198.70           16449.75

ARRIVAL   V00 = -4.389235720D-01 -1.446830200D-01  1.510226860D-02    MAG =  4.624015110D-01   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = -1.323201070D-01 -4.427307150D-01  1.720637390D-02    MAG =  4.624015100D-01   (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL   V00 = -9.492260770D-01 -3.128547830D-01  3.266050870D-02    MAG =  1.000000000D 00   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = -2.861584670D-01 -9.574594930D-01  3.721089470D-02    MAG =  1.000000000D 00   (ECLIPTIC REFERENCE SYSTEM)

HELIOCENTRIC APPROACH ANGLE =  17.9.  DEPART ANGLE =  37.2.  BEND ANGLE =  55.1 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC =   2.3 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED =      0.0 METERS/SECOND.   BEND ANGLE =  55.1 DEGREES.  (PLANETOCENTRIC)

------------------------------------------------------------------------------------------------------------------------------

THIS CASE IS CONVERGED.

    67 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND  27 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

                                JUPITER     SWINGBY CONTINUATION TO      PLUTO

PASS DIST (RADII)  SPEED (M/SEC)  INCLIN (DEG)  NODE (DEG)  ARG PER (DEG)   LEG TIME (DAYS)  MISSION TIME (DAYS)  ARR VINF (M/SEC)
   138.0019          14695.65       21.2108       32.2661      282.826        10961.43           11511.43            4980.72

ARRIVAL   V00 = -4.389235720D-01 -1.446830200D-01  1.510226860D-02    MAG =  4.624015110D-01   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = -4.169648870D-01 -1.968444110D-01  3.475224240D-02    MAG =  4.624015120D-01   (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL   V00 = -9.492260770D-01 -3.128547830D-01  3.266050870D-02    MAG =  1.000000000D 00   (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE V00 = -9.017377250D-01 -4.257001900D-01  7.515598790D-02    MAG =  1.000000000D 00   (ECLIPTIC REFERENCE SYSTEM)

HELIOCENTRIC APPROACH ANGLE =  17.9.  DEPART ANGLE =  11.3.  BEND ANGLE =   7.4 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC =  19.4 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED =      0.0 METERS/SECOND.   BEND ANGLE =   7.4 DEGREES.  (PLANETOCENTRIC)

------------------------------------------------------------------------------------------------------------------------------
```

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO SATURN

FOR SOLUTION HAVING 87.57 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME

JUPITER — START OF TRAJECTORY SEGMENT 2, THRUST OFF

5.500000000D 02	5.765382070D 00	8.977079420D-01	3.276931480D 00	1.951392160D 02	2.099984210D 01	5.434471070D 00	1.757551960D 02
-4.389645530D 00	-3.201889250D 00	1.113246390D-01	-2.049567740D-01	-3.901361820D-01	1.849691440D-02	7.428478930D-01	8.372368350D-03
-1.795472220D-09	3.168591390D-09	-3.832794330D-10	7.185594700D 00	5.130510410D 00	-1.517714160D 00	3.433333340D 01	3.502694500D 00
-2.066518510D 02	-4.535604190D 00	1.134996400D-10	8.368629970D 01	2.886746860D 02	1.057912360D 00	5.244965850D-02	-4.101049280D 05
-2.252316770D 00	-7.098737080D 01	7.100262230D 01	1.173780770D 00	-1.438922920D 02	6.381196010D 01	4.411032230D-01	2.000000000D 02

SATURN — END OF TRAJECTORY, THRUST OFF

1.661942780D 03	5.765382070D 00	8.977079420D-01	3.276931480D 00	1.951392160D 02	4.023640940D 01	9.964945810D 00	1.949917630D 02
-5.664769840D 00	-8.189941880D 00	3.679400130D-01	1.545663150D-02	-1.641008720D-01	9.300747610D-03	7.428478930D-01	2.421162140D-03
1.647955070D 02	1.326563770D 02	-2.745427100D 01	1.034886590D 01	9.740339150D 00	-1.361461600D 00	3.433333340D 01	3.502694500D 00
-2.066518510D 02	-4.535604190D 00	1.134996400D-10	7.871431230D 01	8.248131150D 01	1.057912360D 00	1.516764700D-02	-1.418084080D 06
-1.971764590D 01	6.976934280D 01	7.100262230D 01	2.116037900D 00	-1.246706020D 02	4.997917120D 01	1.650893920D-01	2.000000000D 02

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		75.5		0.0	ON	7.910 01	0.2	71.0	71.0		15.2	ON	0.0
4	8.015	9.2	MIN	0.989		85.2		0.02		8.690 01	0.7	71.0	71.0	MAX	15.2		0.0
4	37.751	43.2		1.041		119.6		0.11	MAX	1.000 02	2.1	71.0	71.0		14.2		0.0
4	86.639	87.9		1.335	MAX	179.3		0.35		7.680 01	4.2	70.9	71.0		10.0		0.0
4	200.000	137.5		2.400		92.4		2.13	OFF	8.880-14	10.9	70.6	71.0		3.7		0.0
5	346.365	161.2		3.784	MIN	0.8		4.78		-6.730 01	*****	******	*****		0.0		90.0
5	388.781	165.2		4.153		31.4	MAX	4.96		-8.430 01	*****	******	*****		0.0		90.0
5	515.840	174.0		5.177		153.0	MIN	4.27		-1.340 02	*****	******	*****		0.0		90.0
7	539.505	175.2		5.356	MAX	178.6		4.35		-1.440 02	*****	******	*****		0.0		90.0
5	550.000	175.8		5.434		168.1		4.44	OFF	-1.480 02	*****	******	*****		0.0	ON	90.0
0	550.000	175.8		5.434		168.1		4.44	OFF	-4.100 05	*****	******	*****		0.0		90.0
6	731.512	181.0		6.554	MIN	1.3		7.55		-5.980 05	*****	******	*****		0.0		90.0
8	752.623	181.5		6.671		18.2	MAX	7.60		-6.200 05	*****	******	*****		0.0		90.0
6	900.685	184.6		7.424		164.4	MIN	6.45		-7.710 05	*****	******	*****		0.0		90.0
7	914.720	184.9		7.490	MAX	178.1		6.48		-7.850 05	*****	******	*****		0.0		90.0
6	1103.761	188.1		8.297	MIN	1.6		9.29		-9.700 05	*****	******	*****		0.0		90.0
8	1117.626	188.3		8.351		12.4	MAX	9.31		-9.830 05	*****	******	*****		0.0		90.0
6	1276.156	190.5		8.917		169.3	MIN	7.92		-1.130 06	*****	******	*****		0.0		90.0
6	1285.867	190.6		8.948	MAX	177.8		7.94		-1.130 06	*****	******	*****		0.0		90.0
8	1473.820	192.9		9.508	MIN	1.8		10.50		-1.290 06	*****	******	*****		0.0		90.0
8	1492.989	193.0		9.532		8.5	MAX	10.51		-1.290 06	*****	******	*****		0.0		90.0
5	1649.209	194.8		9.937		172.9	MIN	8.93		-1.410 06	*****	******	*****		0.0		90.0
6	1655.563	194.9		9.951	MAX	177.6		8.94		-1.410 06	*****	******	*****		0.0		90.0
4	1661.943	195.0		9.965		172.8		8.96	OFF	-1.420 06	*****	******	*****		0.0	ON	90.0

MAY 22, 1965 1.34899333D 01 G.M.T.
2445208.0620D 00 JULIAN DATE PASS SATURN AT 6.980 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-5.66477230 00	-8.18994150 00	3.67940180-01	2.48276110-01	-1.85358830-01	-6.67738280-03	9.96494700 00	2.116	-124.671
S/C	-5.66476980 00	-8.18994190 00	3.67940010-01	1.54566310-02	-1.64100870-01	9.30074760-03	9.96494580 00	2.116	-124.671

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND SATURN IS 195.1226 DEGREES.

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO URANUS

FOR SOLUTION HAVING 23.71 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME

JUPITER — START OF TRAJECTORY SEGMENT 2, THRUST OFF

5.50000000D 02	-8.46638268D 00	1.42407350D 00	1.71543728D 00	7.92754871D 01	1.36819405D 02	5.43447107D 00	1.75755196D 02
-4.38964553D 00	-3.20188925D 00	1.11324630D-01	-3.37840037D-02	-6.96409075D-01	-2.88704438D-03	7.42847893D-01	8.37236835D-03
-1.79547222D-09	3.16859139D-09	-3.53279433D-10	7.18559470D 00	5.13051041D 00	-1.51771416D 00	3.43333334D 01	3.81131046D 00
-2.06651851D 02	-4.53560419D 00	1.13499640D-10	8.36862997D 01	2.88674686D 02	2.95013851D 00	5.24496585D-02	-4.10104928D 05
-6.32684292D 00	-7.08817021D 01	7.10026223D 01	1.17378077D 00	-1.43892292D 02	3.88687142D 01	6.97234031D-01	2.00000000D 02

URANUS — END OF TRAJECTORY, THRUST OFF

2.26390475D 03	-8.46638268D 00	1.42407350D 00	1.71543728D 00	7.92754871D 01	1.84368961D 02	1.91893540D 01	2.23304751D 02
-2.12486619D 00	-1.99712962D 01	-4.37604997D-02	1.03366100D-01	-4.60024655D-01	-5.60540756D-03	7.42847893D-01	6.04359765D-04
2.25721585D 02	2.08058742D 02	-4.02991913D 01	7.55551802D 00	8.63100723D 00	-1.23827865D 00	3.43333334D 01	3.81131046D 00
-2.06651851D 02	-4.53560419D 00	1.13499640D-10	7.69102467D 01	8.36662422D 01	2.95013851D 00	3.78608082D-03	-5.68084997D 06
-9.21894146D 00	7.07442985D 01	7.10026223D 01	-1.30660683D-01	-9.63575023D 01	7.09712376D 01	4.71528000D-01	2.00000000D 02

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		75.5		0.0	ON	7.910 01	0.2	71.0	71.0		15.2	ON	0.0
4	8.015	9.2	MIN	0.989		85.2		0.02		8.690 01	0.7	71.0	71.0	MAX	15.2		0.0
4	37.751	43.2		1.041		119.6		0.11	MAX	1.000 02	2.1	71.0	71.0		14.2		0.0
4	86.639	87.9		1.335	MAX	179.3		0.35		7.680 01	4.2	70.9	71.0		10.0		0.0
4	200.000	137.5		2.490		92.4		2.13	OFF	8.880-14	10.9	70.6	71.0		3.7		0.0
5	246.365	161.2		3.784	MIN	0.8		4.78		-6.730 01	*****	******	*****		0.0		90.0
5	388.781	165.2		4.153		31.4	MAX	4.96		-8.430 01	*****	******	*****		0.0		90.0
5	515.840	174.0		5.177		153.0	MIN	4.27		-1.340 02	*****	******	*****		0.0		90.0
7	539.505	175.2		5.356	MAX	178.6		4.35		-1.440 02	*****	******	*****		0.0		90.0
5	550.000	175.8		5.434		168.1		4.44	OFF	-1.480 02	*****	******	*****		0.0	ON	90.0
0	550.000	175.8		5.434		168.1		4.44	OFF	-4.100 05	*****	******	*****		0.0		90.0
6	740.954	190.5		6.947	MIN	0.7		7.94		-6.730 05	*****	******	*****		0.0		90.0
5	775.820	192.5		7.232		25.5	MAX	8.07		-7.310 05	*****	******	*****		0.0		90.0
6	902.073	198.7		8.276		150.5	MIN	7.39		-9.640 05	*****	******	*****		0.0		90.0
7	930.180	199.8		8.510	MAX	179.4		7.50		-1.020 06	*****	******	*****		0.0		90.0
4	1121.832	206.3		10.099	MIN	0.3		11.08		-1.460 06	*****	******	*****		0.0		90.0
5	1153.698	207.2		10.362		28.9	MAX	11.21		-1.540 06	*****	******	*****		0.0		90.0
6	1279.166	210.3		11.393		151.4	MIN	10.50		-1.880 06	*****	******	*****		0.0		90.0
10	1306.948	210.9		11.621	MAX	179.7		10.61		-1.960 06	*****	******	*****		0.0		90.0
6	1495.122	214.5		13.149	MIN	0.1		14.13		-2.540 06	*****	******	*****		0.0		90.0
9	1524.947	215.0		13.389		27.9	MAX	14.25		-2.640 06	*****	******	*****		0.0		90.0
10	1651.639	216.9		14.474		152.4	MIN	13.50		-3.080 06	*****	******	*****		0.0		90.0
7	1678.828	217.2		14.621	MAX	179.9		13.61		-3.180 06	*****	******	*****		0.0		90.0
7	1865.364	219.5		16.096	MIN	0.0		17.08		-3.900 06	*****	******	*****		0.0		90.0
7	1893.773	219.9		16.319		27.1	MAX	17.19		-4.020 06	*****	******	*****		0.0		90.0
9	2021.811	221.2		17.320		153.2	MIN	16.41		-4.560 06	*****	******	*****		0.0		90.0
7	2048.452	221.4		17.527	MAX	179.9		16.51		-4.680 06	*****	******	*****		0.0		90.0
8	2234.057	223.1		18.960	MIN	0.1		19.94		-5.540 06	*****	******	*****		0.0		90.0
12	2261.428	223.3		19.170		26.4	MAX	20.05		-5.670 06	*****	******	*****		0.0		90.0
5	2263.905	223.3		19.189		28.8		20.05	OFF	-5.680 06	*****	******	*****		0.0	ON	90.0

JANUARY 14, 1987 1.25771586D 01 G.M.T.
2446810.0240 00 JULIAN DATE PASS URANUS AT 13.151 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-2.1248665D 00	-1.9071297D 01	-4.3760497D-02	2.2561311D-01	-3.5772170D-02	-3.0587067D-03	1.9189355D 01	-0.131	-96.358
S/C	-2.1248662D 00	-1.9071296D 01	-4.3760500D-02	1.0336610D-01	-4.6002466D-01	-5.6054076D-03	1.9189354D 01	-0.131	-96.358

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND URANUS IS 223.2905 DEGREES.

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO NEPTUNE

FOR SOLUTION HAVING 11.12 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME

JUPITER — START OF TRAJECTORY SEGMENT 2, THRUST OFF

5.50000000D 02	-3.99762465D 00	2.14684389D 00	1.25771449D 00	1.47161184D 02	6.89511517D 01	5.43447107D 00	1.75755196D 02
-4.38964553D 00	-3.20188925D 00	1.11324630D-01	1.21099292D-01	-7.76748701D-01	1.28864575D-02	7.42847893D-01	8.37236835D-03
-1.79547222D-09	3.16859139D-09	-3.53279433D-10	7.18559470D 00	5.13051041D 00	-1.51771416D 00	3.43333334D 01	3.13450482D 00
-2.06651851D 02	-4.53560419D 00	1.13495640D-10	8.36662997D 01	2.88674686D 02	3.79831307D 00	5.24496585D-02	-4.10104928D 05
-4.71762924D 00	-7.09355538D 01	7.10026223D 01	1.17378977D 00	-1.43892292D 02	2.72578102D 01	7.86237651D-01	2.00000000D 02

NEPTUNE — END OF TRAJECTORY, THRUST OFF

3.19869723D 02	-3.99762465D 00	2.14684389D 00	1.25771449D 00	1.47161184D 02	1.33487076D 02	3.02725129D 01	2.40291120D 02
5.59660057D 00	-2.97467761D 01	4.82090057D-01	2.24638129D-01	-5.15466864D-01	6.83405817D-03	7.42847893D-01	2.26469214D-04
3.23205460D 02	3.33633392D 02	-6.23100164D 01	6.56603603D 00	8.35531601D 00	-1.28261722D 00	3.43333334D 01	3.13450482D 00
-2.06651851D 02	-4.53560419D 00	1.13495640D-10	7.49547619D 01	8.22760451D 01	3.79831307D 00	1.41874227D-03	-1.51600158D 07
-7.40231709D 00	7.08367639D 01	7.10026223D 01	9.12474407D-01	-7.93448466D 01	7.71072707D 01	5.62330047D-01	2.00000000D 02

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		75.5		0.0	ON	7.91D 01	0.2	71.0	71.0		15.2	ON	0.0
4	8.015	9.2	MIN	0.989		85.2		0.02		8.69D 01	0.7	71.0	71.0	MAX	15.2		0.0
4	37.751	43.2		1.041		119.6		0.11	MAX	1.00D 02	2.1	71.0	71.0		14.2		0.0
4	86.639	87.0		1.335	MAX	179.3		0.35		7.68D 01	4.2	70.9	71.0		10.0		0.0
4	200.000	137.5		2.400		92.4		2.13	OFF	8.88D-14	10.9	70.6	71.0		3.7		0.0
5	346.365	161.2		3.784	MIN	0.8		4.78		-6.73D 01	*****	******	*****		0.0		90.0
5	368.781	165.2		4.153		31.4	MAX	4.96		-8.43D 01	*****	******	*****		0.0		90.0
5	515.840	174.0		5.177		153.0	MIN	4.27		-1.34D 02	*****	******	*****		0.0		90.0
7	539.505	175.2		5.356	MAX	178.6		4.35		-1.44D 02	*****	******	*****		0.0		90.0
5	550.000	175.8		5.434		168.1		4.44	OFF	-1.48D 02	*****	******	*****		0.0	ON	90.0
0	550.000	175.8		5.434		168.1		4.44	OFF	-4.10D 05	*****	******	*****		0.0		90.0
6	745.979	195.6		6.893	MIN	1.1		7.88		-6.63D 05	*****	******	*****		0.0		90.0
8	784.131	198.4		7.217		31.8	MAX	8.03		-7.28D 05	*****	******	*****		0.0		90.0
8	906.018	206.1		8.301		146.5	MIN	7.44		-9.70D 05	*****	******	*****		0.0		90.0
7	938.468	207.8		8.598	MAX	178.6		7.58		-1.04D 06	*****	******	*****		0.0		90.0
8	1131.245	215.9		10.415	MIN	1.1		11.40		-1.56D 06	*****	******	*****		0.0		90.0
6	1169.505	217.1		10.781		34.7	MAX	11.58		-1.67D 06	*****	******	*****		0.0		90.0
6	1283.544	220.5		11.891		145.1	MIN	11.04		-2.05D 06	*****	******	*****		0.0		90.0
7	1317.882	221.3		12.213	MAX	178.8		11.20		-2.17D 06	*****	******	*****		0.0		90.0
6	1505.931	225.5		14.039	MIN	1.0		15.02		-2.92D 06	*****	******	*****		0.0		90.0
7	1542.987	226.1		14.400		34.8	MAX	15.20		-3.08D 06	*****	******	*****		0.0		90.0
7	1656.081	228.0		15.499		145.2	MIN	14.66		-3.60D 06	*****	******	*****		0.0		90.0
10	1690.693	228.6		15.835	MAX	178.9		14.82		-3.77D 06	*****	******	*****		0.0		90.0
7	1876.678	231.1		17.640	MIN	1.0		18.62		-4.74D 06	*****	******	*****		0.0		90.0
7	1912.717	231.5		17.989		34.5	MAX	18.79		-4.95D 06	*****	******	*****		0.0		90.0
9	2026.130	232.7		19.085		145.6	MIN	18.24		-5.62D 06	*****	******	*****		0.0		90.0
11	2060.645	233.1		19.419	MAX	178.9		18.40		-5.83D 06	*****	******	*****		0.0		90.0
7	2245.544	234.7		21.230	MIN	0.9		22.18		-7.03D 06	*****	******	*****		0.0		90.0
8	2280.795	235.0		21.539		34.1	MAX	22.35		-7.28D 06	*****	******	*****		0.0		90.0
9	2394.784	235.9		22.633		146.0	MIN	21.79		-8.10D 06	*****	******	*****		0.0		90.0
7	2429.130	236.2		22.962	MAX	179.0		21.95		-8.35D 06	*****	******	*****		0.0		90.0
6	2613.364	237.4		24.722	MIN	0.9		25.71		-9.79D 06	*****	******	*****		0.0		90.0
9	2796.746	238.4		26.463	MAX	179.0		25.45		-1.13D 07	*****	******	*****		0.0		90.0
7	2980.541	239.3		28.211	MIN	0.9		29.19		-1.30D 07	*****	******	*****		0.0		90.0
8	3163.836	240.2		29.943	MAX	179.1		28.93		-1.48D 07	*****	******	*****		0.0		90.0
4	3198.697	240.3		30.273		145.7		29.43	OFF	-1.52D 07	*****	******	*****		0.0	ON	90.0

AUGUST 6, 1989 7.5567315 3D 00 G.M.T.
2447744.8170 00 JULIAN DATE   PASS   NEPTUNE   AT 16.450 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	5.5966006D 00	-2.9746776D 01	4.8209006D-01	1.7783078D-01	3.4707872D-02	-4.8202658D-03	3.0272513D 01	0.912	-79.345
S/C	5.5966006D 00	-2.9746776D 01	4.8209006D-01	2.2463813D-01	-5.1546686D-01	6.8340582D-03	3.0272513D 01	0.912	-79.345

TWO-BODY TRANSFER ANGLE BETWEEN   EARTH   AND   NEPTUNE   IS 240.3072 DEGREES.

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO PLUTO

FOR SOLUTION HAVING 138.00 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME

JUPITER START OF TRAJECTORY SEGMENT 2. THRUST OFF

5.50000000D 02	1.70643920D 01	8.98935760D-01	3.85012376D 00	1.98382516D 02	1.77627688D 01	5.43447107D 00	1.75755196D 02
-4.38964553D 00	-3.20188925D 00	1.11324630D-01	-1.63545488D-01	-5.30862397D-01	3.04323260D-02	7.42847893D-01	8.37236835D-03
-1.79547222D-09	3.16659139D-09	-3.53279433D-10	7.18559470D 00	5.13051041D 00	-1.51771416D 00	3.43333334D 01	3.94495422D 00
-2.06651851D 02	-4.53560415D 00	1.13499640D-10	8.36862997D 01	2.88674686D 02	1.81072983D 00	5.24496585D-02	-4.10104928D 05
-1.67805636D 00	-7.09941591D 01	7.10026223D 01	1.17378077D 00	-1.43892292D 02	5.32068644D 01	5.56316580D-01	2.00000000D 02

ARRAYS IN LABELLED COMMON BLOCK EXTREM FILLED. STORAGE OF DATA IN EXTREM TERMINATED.

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THETA	PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		75.5		0.0	ON	7.91D 01	0.2	71.0	71.0		15.2	ON	0.0
4	8.015	9.2	MIN	0.989		85.2		0.02		8.69D 01	0.7	71.0	71.0	MAX	15.2		0.0
4	37.751	43.2		1.041		119.6		0.11	MAX	1.00D 02	2.1	71.0	71.0		14.2		0.0
4	86.639	87.9		1.335	MAX	179.3		0.35		7.68D 01	4.2	70.9	71.0		10.0		0.0
4	200.000	137.5		2.400		92.4		2.13	OFF	8.88D-14	10.9	70.6	71.0		3.7		0.0
5	346.365	161.2		3.784	MIN	0.8		4.78		-6.73D 01	*****	******	*****		0.0		90.0
5	389.781	165.2		4.153		31.4	MAX	4.96		-8.43D 01	*****	******	*****		0.0		90.0
5	515.840	174.0		5.177		153.0	MIN	4.27		-1.34D 02	*****	******	*****		0.0		90.0
7	539.505	175.2		5.356	MAX	178.6		4.35		-1.44D 02	*****	******	*****		0.0		90.0
5	550.000	175.8		5.434		168.1		4.44	OFF	-1.48D 02	*****	******	*****		0.0	ON	90.0
0	550.000	175.8		5.434		168.1		4.44	OFF	-4.10D 05	*****	******	*****		0.0		90.0
6	735.134	184.7		6.789	MIN	1.5		7.78		-6.42D 05	*****	******	*****		0.0		90.0
5	762.833	185.7		6.981		23.7	MAX	7.87		-6.80D 05	*****	******	*****		0.0		90.0
8	900.265	190.1		7.900		157.9	MIN	6.96		-8.76D 05	*****	******	*****		0.0		90.0
7	920.734	190.7		8.032	MAX	177.6		7.02		-9.07D 05	*****	******	*****		0.0		90.0
6	1110.944	195.3		9.268	MIN	2.1		10.20		-1.20D 06	*****	******	*****		0.0		90.0
5	1132.968	195.8		9.339		19.9	MAX	10.26		-1.24D 06	*****	******	*****		0.0		90.0
5	1276.507	198.5		10.166		161.1	MIN	9.21		-1.48D 06	*****	******	*****		0.0		90.0
8	1294.312	198.8		10.265	MAX	177.2		9.25		-1.51D 06	*****	******	*****		0.0		90.0
6	1482.477	201.7		11.283	MIN	2.4		12.27		-1.84D 06	*****	******	*****		0.0		90.0
7	1501.210	201.9		11.381		17.4	MAX	12.32		-1.87D 06	*****	******	*****		0.0		90.0
6	1649.131	203.8		12.135		163.3	MIN	11.16		-2.14D 06	*****	******	*****		0.0		90.0
9	1665.024	204.0		12.214	MAX	177.0		11.20		-2.17D 06	*****	******	*****		0.0		90.0
8	1852.113	206.1		13.118	MIN	2.7		14.10		-2.53D 06	*****	******	*****		0.0		90.0
5	1868.580	206.3		13.196		15.6	MAX	14.14		-2.56D 06	*****	******	*****		0.0		90.0
6	2019.883	207.7		13.890		164.9	MIN	12.91		-2.85D 06	*****	******	*****		0.0		90.0
7	2034.286	207.9		13.955	MAX	176.8		12.94		-2.88D 06	*****	******	*****		0.0		90.0
7	2220.700	209.5		14.771	MIN	2.8		15.76		-3.25D 06	*****	******	*****		0.0		90.0
6	2235.457	209.6		14.834		14.2	MAX	15.79		-3.28D 06	*****	******	*****		0.0		90.0
5	2389.506	210.8		15.479		166.2	MIN	14.49		-3.59D 06	*****	******	*****		0.0		90.0
8	2402.689	210.9		15.533	MAX	176.7		14.52		-3.62D 06	*****	******	*****		0.0		90.0
7	2588.633	212.2		16.278	MIN	2.9		17.26		-4.00D 06	*****	******	*****		0.0		90.0
6	2602.022	212.3		16.330		13.1	MAX	17.29		-4.02D 06	*****	******	*****		0.0		90.0
6	2758.379	213.3		16.931		167.2	MIN	15.94		-4.35D 06	*****	******	*****		0.0		90.0
8	2770.529	213.4		16.977	MAX	176.6		15.96		-4.37D 06	*****	******	*****		0.0		90.0
7	2956.123	214.5		17.601	MIN	3.0		18.65		-4.76D 06	*****	******	*****		0.0		90.0
6	2968.374	214.6		17.706		12.1	MAX	18.67		-4.78D 06	*****	******	*****		0.0		90.0
6	3126.724	215.4		18.267		168.1	MIN	17.27		-5.11D 06	*****	******	*****		0.0		90.0
8	3137.975	215.5		18.307	MAX	176.6		17.29		-5.14D 06	*****	******	*****		0.0		90.0
8	3323.295	216.5		18.939	MIN	3.1		19.92		-5.52D 06	*****	******	*****		0.0		90.0
8	3334.573	216.5		18.977		11.3	MAX	19.94		-5.55D 06	*****	******	*****		0.0		90.0
9	3494.678	217.3		19.504		168.9	MIN	18.51		-5.88D 06	*****	******	*****		0.0		90.0
8	3505.132	217.3		19.538	MAX	176.5		18.52		-5.90D 06	*****	******	*****		0.0		90.0
10	3690.229	218.2		20.124	MIN	3.2		21.11		-6.29D 06	*****	******	*****		0.0		90.0
9	3701.656	218.2		20.157		10.6	MAX	21.12		-6.31D 06	*****	******	*****		0.0		90.0
10	3862.332	218.9		20.651		169.6	MIN	19.65		-6.65D 06	*****	******	*****		0.0		90.0
9	3872.069	219.0		20.691	MAX	176.5		19.67		-6.67D 06	*****	******	*****		0.0		90.0
8	4056.980	219.7		21.226	MIN	3.2		22.21		-7.05D 06	*****	******	*****		0.0		90.0
6	4066.649	219.7		21.254		9.9	MAX	22.22		-7.07D 06	*****	******	*****		0.0		90.0
8	4229.750	220.4		21.719		170.2	MIN	20.72		-7.41D 06	*****	******	*****		0.0		90.0
8	4238.835	220.4		21.745	MAX	176.4		20.73		-7.43D 06	*****	******	*****		0.0		90.0
7	4423.586	221.1		22.253	MIN	3.3		23.24		-7.81D 06	*****	******	*****		0.0		90.0
7	4432.572	221.1		22.277		9.3	MAX	23.25		-7.83D 06	*****	******	*****		0.0		90.0
7	4596.978	221.7		22.715		170.8	MIN	21.71		-8.16D 06	*****	******	*****		0.0		90.0
7	4605.463	221.7		22.737	MAX	176.4		21.72		-8.18D 06	*****	******	*****		0.0		90.0
8	4790.075	222.4		23.211	MIN	3.3		24.19		-8.55D 06	*****	******	*****		0.0		90.0
8	4798.437	222.4		23.232		8.8	MAX	24.20		-8.56D 06	*****	******	*****		0.0		90.0
10	4964.050	222.9		23.643		171.3	MIN	22.64		-8.89D 06	*****	******	*****		0.0		90.0

11	4971.978	223.0	23.663	MAX	176.4		22.65	-8.91D 06	*****	******	*****	0.0		90.0
9	5156.467	223.5	24.105	MIN	3.4		25.09	-9.27D 06	*****	******	*****	0.0		90.0
9	5164.255	223.6	24.124		8.3	MAX	25.10	-9.29D 06	*****	******	*****	0.0		90.0
9	5330.994	224.1	24.510		171.8	MIN	23.51	-9.61D 06	*****	******	*****	0.0		90.0
9	5338.401	224.1	24.527	MAX	176.3		23.51	-9.63D 06	*****	******	*****	0.0		90.0
9	5522.780	224.6	24.940	MIN	3.4		25.92	-9.98D 06	*****	******	*****	0.0		90.0
8	5530.033	224.6	24.956		7.9	MAX	25.93	-9.99D 06	*****	******	*****	0.0		90.0
7	5697.829	225.1	25.319		172.2	MIN	24.31	-1.03D 07	*****	******	*****	0.0		90.0
10	5704.745	225.1	25.334	MAX	176.3		24.32	-1.03D 07	*****	******	*****	0.0		90.0
9	5889.025	225.6	25.720	MIN	3.4		26.70	-1.07D 07	*****	******	*****	0.0		90.0
9	5895.778	225.7	25.733		7.4	MAX	26.71	-1.07D 07	*****	******	*****	0.0		90.0
9	6064.572	226.1	26.074		172.6	MIN	25.07	-1.10D 07	*****	******	*****	0.0		90.0
10	6071.024	226.1	26.087	MAX	176.3		25.07	-1.10D 07	*****	******	*****	0.0		90.0
9	6255.213	226.6	26.446	MIN	3.5		27.43	-1.13D 07	*****	******	*****	0.0		90.0
9	6261.494	226.6	26.458		7.1	MAX	27.43	-1.13D 07	*****	******	*****	0.0		90.0
9	6431.236	227.0	26.778		173.0	MIN	25.77	-1.16D 07	*****	******	*****	0.0		90.0
9	6437.247	227.1	26.789	MAX	176.3		25.78	-1.16D 07	*****	******	*****	0.0		90.0
8	6987.448	228.4	27.753	MIN	3.5		28.73	-1.26D 07	*****	******	*****	0.0		90.0
7	6992.858	228.4	27.762		6.4	MAX	28.74	-1.26D 07	*****	******	*****	0.0		90.0
10	7164.369	228.8	28.041		173.6	MIN	27.03	-1.28D 07	*****	******	*****	0.0		90.0
8	7169.554	228.8	28.049	MAX	176.2		27.03	-1.29D 07	*****	******	*****	0.0		90.0
9	7353.508	229.2	28.337	MIN	3.5		29.32	-1.31D 07	*****	******	*****	0.0		90.0
10	7358.511	229.2	28.345		6.0	MAX	29.32	-1.32D 07	*****	******	*****	0.0		90.0
8	7530.854	229.6	28.604		173.9	MIN	27.59	-1.34D 07	*****	******	*****	0.0		90.0
9	7535.650	229.6	28.611	MAX	176.2		27.60	-1.34D 07	*****	******	*****	0.0		90.0
10	7719.536	230.0	28.877	MIN	3.5		29.86	-1.37D 07	*****	******	*****	0.0		90.0
8	7724.148	230.0	28.884		5.8	MAX	29.86	-1.37D 07	*****	******	*****	0.0		90.0
10	7897.295	230.4	29.124		174.2	MIN	28.11	-1.39D 07	*****	******	*****	0.0		90.0
13	7901.714	230.4	29.130	MAX	176.2		28.12	-1.40D 07	*****	******	*****	0.0		90.0
8	8085.536	230.8	29.375	MIN	3.6		30.36	-1.42D 07	*****	******	*****	0.0		90.0
7	8455.383	231.5	29.837		5.2	MAX	30.82	-1.47D 07	*****	******	*****	0.0		90.0
8	8630.065	231.9	30.041		174.7	MIN	29.03	-1.49D 07	*****	******	*****	0.0		90.0
9	8633.764	231.9	30.045	MAX	176.2		29.03	-1.49D 07	*****	******	*****	0.0		90.0
12	8817.466	232.3	30.250	MIN	3.6		31.23	-1.51D 07	*****	******	*****	0.0		90.0
9	8820.983	232.3	30.254		5.0	MAX	31.23	-1.51D 07	*****	******	*****	0.0		90.0
10	8996.403	232.6	30.440		174.9	MIN	29.43	-1.53D 07	*****	******	*****	0.0		90.0
14	8999.755	232.6	30.444	MAX	176.2		29.43	-1.53D 07	*****	******	*****	0.0		90.0
10	9183.402	233.0	30.629	MIN	3.6		31.61	-1.55D 07	*****	******	*****	0.0		90.0
11	9552.158	233.7	30.973		4.6	MAX	31.95	-1.59D 07	*****	******	*****	0.0		90.0
8	9729.003	234.0	31.124		175.3	MIN	30.11	-1.61D 07	*****	******	*****	0.0		90.0
9	9731.685	234.0	31.127	MAX	176.1		30.11	-1.61D 07	*****	******	*****	0.0		90.0
12	9915.227	234.3	31.275	MIN	3.6		32.26	-1.63D 07	*****	******	*****	0.0	ON	90.0

MAY 10, 2012 1.19646049D 02 G.M.T.
2456257.550D 00 JULIAN DATE PASS PLUTO AT 4.081 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	4.1945415D 00	-3.1839326D 01	2.1224266D 00	1.8429087D-01	-1.2639652D-02	-5.2214033D-02	3.2184493D 01	3.781	-82.495
S/C	4.1945415D 00	-3.1839326D 01	2.1224266D 00	5.8512926D-02	-1.3438638D-02	2.1000884D-03	3.2184493D 01	3.781	-82.495

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND PLUTO IS 237.2333 DEGREES.

E. ENCKE RENDEZVOUS WITH DOUBLE ASTEROID FLYBY

This example exhibits the multiple target mission capability of HILTOP. The specific example consists of an 830 day rendezvous mission to Encke, arriving 30 days prior to perihelion passage in the 1987 apparition, and encountering the asteroids Metis and Amherstia at approximately 255 and 551 days, respectively, into the mission. The launch vehicle is the Titan III E/Centaur while the solar electric propulsion system is characterized by a reference power of 10 kilowatts, a specific impulse of 2900 seconds and an efficiency factor of 0.61. Because this particular mission results in a nominally high launch asymptote declination, the non-coplanar launch maneuver logic is implemented by setting LAUNCH = 1. The asymptote declination is optimized subject to the constraint that the parking orbit inclination be no greater than 32.5 degrees. The constrained declination case was obtained in a sequence of fixed declination trajectories, commencing with the unconstrained case. In this sequence, it was observed that the initial primer vector was attempting to sweep through the North Pole. To permit this to happen, it is necessary to define the right ascension of the asymptote to be 180 degrees from the initial primer. This is achieved by setting PSIGN equal to -1. Many helpful suggestions for the use of HILTOP in studying multiple target missions are given in Reference [12].

The inputs to the sample case shown represent converged values for a reference power of about 9 kilowatts. From these starting conditions a converged solution for 10 kilowatts was achieved after 5 iterations. The complete input data set is reproduced below and is followed by the program printout associated with NPRINT = 3 and MPRINT = 0.

```
&INPUT
X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0,X6(2)=1.D0
X7=1.D0,X10(2)=1.D0,X11(2)=1.D0,X12=2.0439285D4,X13(2)=1.D0
X15=-860.D0,X16=-30.D0
X41(2)=1.D0,X42(2)=1.D0,X43(2)=1.D0,X44(2)=1.D0,X45(2)=1.D0,X46(2)=1.D0
X48=-603.D0,1.D0
X51(2)=1.D0,X52(2)=1.D0,X53(2)=1.D0,X54(2)=1.D0,X55(2)=1.D0,X56(2)=1.D0
X58=-306.D0,1.D0
Y1(2)=1.D0,1.D-5,Y2(2)=1.D0,1.D-5,Y3(2)=1.D0,1.D-5,Y4(2)=1.D0,1.D-5
Y5(2)=1.D0,1.D-5,Y6(2)=1.D0,1.D-5,Y10(2)=1.D0,1.D-5,Y11=1.D1,3.D2,1.D-6
Y13(2)=1.D0,1.D-5,Y41(2)=1.D0,1.D-5,Y42(2)=1.D0,1.D-5,Y43(2)=1.D0,1.D-5
Y44(2)=2.D0,1.D-5,Y45(2)=2.D0,1.D-5,Y46(2)=2.D0,1.D-5,Y48(2)=1.D0,1.D-5
Y51(2)=1.D0,1.D-5,Y52(2)=1.D0,1.D-5,Y53(2)=1.D0,1.D-5,Y54(2)=2.D0,1.D-5
Y55(2)=2.D0,1.D-5,Y56(2)=2.D0,1.D-5,Y58(2)=1.D0,1.D-5
CNIX(1)=5.531D0,ECIX(1)=.122D0,OMIX(1)=68.79D0,SOIX(1)=4.768D0
SAIX(1)=2.3863D0,TPIX(1)=-199.D0
CNIX(2)=13.035D0,ECIX(2)=.2732D0,OMIX(2)=330.117D0,SOIX(2)=255.331D0
SAIX(2)=2.6788D0,TPIX(2)=-725.D0
MTMASS=3,NDAY=17,MONTH=07,NYEAR=1987,MODE=5,MOPT2=3,MOPT3=10,MOPTX=2*11
NBOOST=15,ALPHAA=15.D0,ALPHAT=15.285D0,CTANK=.1D0,BI=.61D0,DI=0.D0
NPRINT=3,LAUNCH=1,XANG1=28.5D0,XANG2=32.5D0,GAP=-1.D-4,PSIGN=-1.D0
 X1=-3.72846870000D-01, X2=-2.95979320000D 00, X3=-8.92279920000D 00
 X4=-1.02517880000D 00, X5= 5.91744740000D-01, X6= 8.70042180000D-01
X10=-4.67951070000D 01,X11= 4.12516450000D-04,X13= 8.12521530000D 03
X41=-1.19574930000D 01,X42=-7.84627570000D 00,X43= 1.72536080000D 01
X44= 1.75582590000D 00,X45=-1.23593650000D 00,X46=-3.96075270000D 00
X48=-6.05208250000D 02,X51=-3.51621130000D 00,X52=-4.81369080000D 00
X53=-8.54690200000D 00,X54= 1.92320800000D 00,X55= 3.18719440000D-02
X56= 1.81497220000D 00,X58=-3.09430490000D 02
&END
```

ORIGINAL PAGE IS
OF POOR QUALITY

CASE 1 TIME TO GO CPU 59. I/O 13 SEC

PROGRAM INPUTS

X 1 =	-3.728468700000000D-01	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X 2 =	-2.959793200000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X 3 =	-8.922799200000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X 4 =	-1.025178800000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X 5 =	5.917447400000000D-01	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X 6 =	8.700421800000000D-01	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X 7 =	1.000000000000000D 00	0.0	3.000000000000000D 00	9.999999999999999D-07	1.000000000000000D 00
X 8 =	0.0	0.0	3.000000000000000D 00	9.999999999999999D-07	1.000000000000000D 00
X 9 =	0.0	0.0	3.000000000000000D 00	9.999999999999999D-07	1.000000000000000D 00
X10 =	-4.679510700000000D 01	1.000000000000000D 00	9.000000000000000D 01	9.999999999999999D-07	1.000000000000000D 00
X11 =	4.125164300000000D-04	1.000000000000000D 00	9.999999999999999D-04	1.000000000000000D-11	1.000000000000000D 00
X12 =	2.843928500000000D 04	0.0	2.000000000000000D 03	9.999999999999999D-04	1.000000000000000D 00
X13 =	8.125215300000000D 03	1.000000000000000D 00	5.000000000000000D 02	9.999999999999999D-05	1.000000000000000D 00
X14 =	0.0	0.0	5.000000000000000D 02	9.999999999999999D-04	1.000000000000000D 00
X15 =	-8.600000000000000D 02	0.0	8.000000000000000D 00	9.999999999999999D-07	1.000000000000000D 00
X16 =	-3.000000000000000D 01	0.0	1.000000000000000D 02	9.999999999999999D-07	1.000000000000000D 00
X17 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X18 =	0.0	0.0	1.000000000000000D 00	9.999999999999999D-05	1.000000000000000D 00
X19 =	0.0	0.0	1.000000000000000D 00	9.999999999999999D-05	1.000000000000000D 00
X20 =	0.0	0.0	1.000000000000000D 00	9.999999999999999D-05	1.000000000000000D 00
X21 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X22 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X23 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X24 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X25 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X26 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X27 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X28 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X29 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X30 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X31 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X32 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X33 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X34 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X35 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X36 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X37 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X38 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X39 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X40 =	0.0	0.0	1.000000000000000D 01	9.999999999999999D-05	1.000000000000000D 00
X41 =	-1.155749800000000D 01	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X42 =	-7.846275700000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X43 =	1.725960800000000D 01	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X44 =	1.753925900000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X45 =	-1.235936500000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X46 =	-3.960752700000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X47 =	0.0	0.0	5.000000000000000D 02	9.999999999999999D-05	1.000000000000000D 00
X48 =	-6.052082500000000D 02	1.000000000000000D 00	5.000000000000000D 01	9.999999999999999D-07	1.000000000000000D 00
X49 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X50 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X51 =	-3.516211300000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X52 =	-4.819690800000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X53 =	-8.546962000000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X54 =	1.028208000000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X55 =	3.187194400000000D-02	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X56 =	1.814972200000000D 00	1.000000000000000D 00	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
X57 =	0.0	0.0	5.000000000000000D 02	9.999999999999999D-05	1.000000000000000D 00
X58 =	-3.094864899999999D 02	1.000000000000000D 00	5.000000000000000D 01	9.999999999999999D-07	1.000000000000000D 00
X59 =	0.0	0.0	3.000000000000000D 00	1.000000000000000D-08	1.000000000000000D 00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
X61 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X62 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X63 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X64 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X65 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X66 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X67 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X68 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X69 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X70 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
Y 1 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y 2 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y 3 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y 4 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y 5 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y 6 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y 7 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y 8 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y 9 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y10 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y11 =	1.0000000000000000D 01,	3.0000000000000000D 00,	9.9999999999999999D-05,		
Y12 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y13 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y14 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y15 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y16 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y17 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y18 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y19 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y20 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y21 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y22 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y23 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y24 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y25 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y26 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y27 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y28 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y29 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y30 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y31 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y32 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y33 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y34 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y35 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y36 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y37 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y38 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y39 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y40 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y41 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y42 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y43 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y44 =	0.0 ,	2.0000000000000000D 00,	9.9999999999999998D-06,		
Y45 =	0.0 ,	2.0000000000000000D 00,	9.9999999999999998D-06,		
Y46 =	0.0 ,	2.0000000000000000D 00,	9.9999999999999998D-06,		
Y47 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y48 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y49 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y50 =	0.0 ,	0.0 ,	9.9999999999999999D-05,		
Y51 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y52 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y53 =	0.0 ,	1.0000000000000000D 00,	9.9999999999999998D-06,		
Y54 =	0.0 ,	2.0000000000000000D 00,	9.9999999999999998D-06,		
Y55 =	0.0 ,	2.0000000000000000D 00,	9.9999999999999998D-06,		
[illegible]	[illegible]	[illegible]	[illegible]		

```
Y56 = 0.0          .  2.000000000000000D 00,   9.999999999999998D-06,
Y57 =  0.0         .   0.0              .   9.999999999999999D-05,
Y58 =  0.0         .   1.000000000000000D 00,   9.999999999999998D-06,
Y59 =  0.0         .   0.0              .   9.999999999999999D-05,
Y60 =  0.0         .   0.0              .   9.999999999999999D-05,
Y61 =  0.0         .   0.0              .   9.999999999999999D-05,
Y62 =  0.0         .   0.0              .   9.999999999999999D-05,
Y63 =  0.0         .   0.0              .   9.999999999999999D-05,
Y64 =  0.0         .   0.0              .   9.999999999999999D-05,
Y65 =  0.0         .   0.0              .   9.999999999999999D-05,
Y66 =  0.0         .   0.0              .   9.999999999999999D-05,
Y67 =  0.0         .   0.0              .   9.999999999999999D-05,
Y68 =  0.0         .   0.0              .   9.999999999999999D-05,
Y69 =  0.0         .   0.0              .   9.999999999999999D-05,
Y70 =  0.0         .   0.0              .   9.999999999999999D-05,
&OUTPUT
AAI= 0.0            ,AE= 0.0                  ,ALPHAA=  15.00000000000000    ,ALPHAT=  15.28500000000000    ,ALTITU=
 0.0             ,AN=  1.500000000000000     ,AR=  1.000000000000000    ,ASOL= 0.0              , 0.0
 0.0             , 0.0                    , 0.0                    ,BI= 0.6100000000000000   ,B1= 0.0               ,B2=
 0.0             ,B3= 0.0                 ,CNI= 0.0                 ,CNIX=  5.581000000000000   , 13.03500000000000    ,
 0.0             , 0.0                    , 0.0                    ,CSTR= 0.0                ,CTANK= 0.1000000000000000D 00,
CTRET= 0.1111111111111111   ,DI= 0.0          ,DMRETR= 0.0              ,DPOW= 0.0               ,ECI=
 0.0             ,ECIX= 0.1220000000000000    , 0.2732000000000000     , 0.0                   , 0.0
 0.0             ,EI= 0.0                 ,EMUODD= 0.0              ,EMUODX= 0.0              ,
 0.0             , 0.0                    , 0.0                    , 0.0                    ,GAMMAX=  1.000000000000000     ,GAP=
-0.9999999999999999D-04,HOUR=  12.00000000000000    ,OMI= 0.0        ,OMIX=  68.79000000000000     ,
  330.1170000000000    , 0.0                    , 0.0                    , 0.0                    ,POWFIX= -1.000000000000000    ,
FSIGN= -1.000000000000000    ,RADODD=  1.000000000000000    ,RADODX= 0.0           , 0.0
 0.0             , 0.0                    , 0.0                    ,RAP=  38.00000000000000     ,REVS= 0.0               ,
RPER=  2.000000000000000    ,SAI=  1.000000000000000    ,SAIX=  2.386300000000000    , 2.678800000000000    ,
 0.0             , 0.0                    , 0.0                    ,SOI= 0.0                ,SOIX=  4.708000000000000    ,
  255.3310000000000    , 0.0                    , 0.0                    , 0.0                    ,SPIRET=  300.0000000000000    ,
STATE=  1.000000000000000    , 0.0          , 0.0                    , 0.0                    , 1.000000000000000    ,
 0.0             ,STEP1= 0.3125000000000000D-01,STEP2= 0.1250000000000000    ,TCOAST= 0.0
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    ,TDV= -1.000000000000000    ,TGO=
-1.000000000000000    ,THRET=  400.0000000000000    ,TOFF= -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
-1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
-1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
-1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
-1.000000000000000    , -1.000000000000000    ,TPI= 0.0              ,TPIX= -199.0000000000000    , -725.0000000000000    ,
 0.0             , 0.0                    , 0.0                    ,TPOWER= 0.1000000000000000D 31,TSCALE=
  1.000000000000000    ,T2=  50.00000000000000    , 100.0000000000000    , 150.0000000000000    , 200.0000000000000    ,
  250.0000000000000    , 300.0000000000000    , 350.0000000000000    , 400.0000000000000    , 450.0000000000000    ,
  500.0000000000000    ,XANG1=  28.50000000000000    ,XANG2=  32.50000000000000    ,XSWING= 0.0
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    , 0.0                    ,
 0.0             , 0.0                    , 0.0                    , 0.0                    ,X0=  1.000000000000000    ,
 0.0             , 0.0                    , 0.0                    , 1.000001500000000    , 0.0                    ,
 0.0             ,IBAL=            0,INTPR=            0,IOUT=            0,IRK=            1,IRL=            1,IROT=            0,ISPIN=
         0,ITF=            3,ITPRNT=            0,JPP=            0,JPRINT=            0,JT=            0,KPART=            0,LAUNCH=
         1,LOADX=            0,MAXHAM=            5,MBOOST=           15,MDAY=           17,MODE=            5,MONTH=            7,MOPT=
         0,MOPTX=           11,           11,            0,            0,            0,MOPT2=            3,MOPT3=           19,MOPT4=            0,
         0,            0,            0,            0,            0,            0,            0,            0,            0,MPOW=            0,
MPRINT=            0,MPUNCH=            0,MREAD=            0,MSWING=            0,            0,            0,            0,
         0,            0,            0,            0,            0,MTMASS=            3,MUPDAT=            1,MYEAR=         1987,NDIST=
         3,NHUNG=           25,NORMAL=            0,NPERF=            0,NPRINT=            3,NSET=            0,            0,          300,
         0,          300,NSWING=            0,NSWPAR=            1,NTAPE=           17
&END
```

ORIGINAL PAGE IS
OF POOR QUALITY

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	-3.7284687000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	-2.9597932000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-8.9227992000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	-1.0251786000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	5.5174474000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	8.7004218000000000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	10	-4.6795107000000000D 01	5.0000000000000000D 01	9.9999999999999990D-07	1.0000000000000000D 00
8	11	4.1251643000000000D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
9	13	8.1252153000000000D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00
10	41	-1.1957498000000000D 01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
11	42	-7.8462757000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
12	43	1.7259608000000000D 01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
13	44	1.7539259000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
14	45	-1.2359365000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
15	46	-3.9607527000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
16	48	-6.0520825000000000D 02	5.0000000000000000D 01	9.9999999999999990D-07	1.0000000000000000D 00
17	51	-3.5162113000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
18	52	-4.8196908000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
19	53	-8.5469620000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
20	54	1.0282080000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
21	55	3.1871944000000000D-02	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
22	56	1.8149722000000000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
23	58	-3.0548648999999990D 02	5.0000000000000000D 01	9.9999999999999990D-07	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999980D-06
2	2	0.0	9.9999999999999980D-06
3	3	0.0	9.9999999999999980D-06
4	4	0.0	9.9999999999999980D-06
5	5	0.0	9.9999999999999980D-06
6	6	0.0	9.9999999999999980D-06
7	10	0.0	9.9999999999999980D-06
8	11	1.0000000000000000D 01	9.9999999999999990D-05
9	13	0.0	9.9999999999999980D-06
10	41	0.0	9.9999999999999980D-06
11	42	0.0	9.9999999999999980D-06
12	43	0.0	9.9999999999999980D-06
13	44	0.0	9.9999999999999980D-06
14	45	0.0	9.9999999999999980D-06
15	46	0.0	9.9999999999999980D-06
16	48	0.0	9.9999999999999980D-06
17	51	0.0	9.9999999999999980D-06
18	52	0.0	9.9999999999999980D-06
19	53	0.0	9.9999999999999980D-06
20	54	0.0	9.9999999999999980D-06
21	55	0.0	9.9999999999999980D-06
22	56	0.0	9.9999999999999980D-06
23	58	0.0	9.9999999999999980D-06

THIS CASE IS CONVERGED.

14 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 5 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

ORIGINAL PAGE IS
OF POOR QUALITY

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			START OF TRAJECTORY, THRUST ON				
0.0	2.006632550 00	5.102043830-01	5.141932330 00	3.488715520 02	1.800000000 02	9.930187850-01	0.0
-9.743470080-01	1.916617210-01	0.0	-1.353947360-01	-1.218725150 00	-1.099568720-01	1.000000000 00	7.042911910-02
-3.205255620-01	-2.942124460 00	-8.641356830 00	-8.689376260-01	5.179782910-01	6.334698850-01	1.000000000 00	1.409756570 00
0.0	0.0	0.0	9.607559780 01	3.166150770 01	1.218314010 00	1.000000000 00	8.086789420 00
-6.596751320 01	9.390536900 01	9.156945190 01	0.0	1.688715520 02	-4.769962480 00	1.231143070 00	0.0
INPUT TARGET			END OF TRAJECTORY SEGMENT 1, THRUST ON				
2.549037230 02	1.903128110 00	6.014625810-01	1.072117920 01	3.397758750 02	3.320809400 02	2.508968870 00	1.431549280 02
1.681252040 00	-1.849474670 00	-2.185401850-01	5.128557250-01	7.991843940-02	4.776578440-02	8.233662120-01	1.964989650-02
-1.113837930 01	-7.315196300 00	1.655390140 01	-1.284895250 00	-4.942512740-01	4.491074430 00	2.944448310 00	1.409756170 00
-2.022401060 01	-3.200381660-01	0.0	8.245825030 01	2.122988810 02	1.102115120 00	2.297211880-01	1.871198260 01
5.922308290 01	-1.088500240 02	9.951612470 01	-4.997000210 00	-4.772781330 01	3.256906380 01	5.212384500-01	2.549037230 02
INPUT TARGET			START OF TRAJECTORY SEGMENT 2, THRUST ON				
2.549037230 02	1.903128110 00	6.014625810-01	1.072117920 01	3.397758750 02	3.320809400 02	2.508968870 00	1.431549280 02
1.681252040 00	-1.849474670 00	-2.185401850-01	5.128557250-01	7.991843940-02	4.776578440-02	8.233662120-01	1.964989650-02
-1.113837930 01	-7.315196300 00	1.655390140 01	1.643171180 00	-1.136581640 00	-3.754768120 00	2.944448310 00	3.532837140-01
-2.022401060 01	-3.200381660-01	0.0	8.245825030 01	2.122988810 02	1.102115120 00	2.297211880-01	1.871198260 01
5.922308290 01	-1.088500240 02	9.951612470 01	-4.997000210 00	-4.772781330 01	3.256906380 01	5.212384500-01	2.549037230 02
INPUT TARGET			END OF TRAJECTORY SEGMENT 2, THRUST ON				
5.506972600 02	1.759961320 00	7.085360060-01	1.583771200 01	3.334392700 02	1.486017270 01	2.908723110 00	1.797555260 02
2.835619890 00	-6.152093520-01	2.035863870-01	-6.256906220-02	3.311895070-01	7.610026100-02	7.558752120-01	1.633143930-02
-3.312633570 00	-4.373831130 00	-8.018992510 00	1.206502980 00	1.628612390 00	-4.928710120 00	4.275525240 00	3.532837220-01
-3.168807980 01	-5.827063290-01	0.0	7.976426890 01	3.147535640 02	9.361729430-01	1.752759410-01	6.331709740 00
-3.997737790 01	-1.126352330 02	1.071527270 02	4.013508760 00	-1.224104480 01	-2.133619160 01	3.455323820-01	5.506972600 02
INPUT TARGET			START OF TRAJECTORY SEGMENT 3, THRUST ON				
5.506972600 02	1.759961320 00	7.085360060-01	1.583771200 01	3.334392700 02	1.486017270 01	2.908723110 00	1.797555260 02
2.835619890 00	-6.152093520-01	2.035863870-01	-6.256906220-02	3.311895070-01	7.610026100-02	7.558752120-01	1.633143930-02
-3.312633570 00	-4.373831130 00	-8.018992510 00	9.612884980-01	-1.962334460-02	1.715538430 00	4.275525240 00	3.781902130-01
-3.168807980 01	-5.827063290-01	0.0	7.976426890 01	3.147535640 02	9.361729430-01	1.752759410-01	6.331709740 00
-3.997737790 01	-1.126352330 02	1.071527270 02	4.013508760 00	-1.224104480 01	-2.133619160 01	3.455323820-01	5.506972600 02

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
			SWITCH THRUST OFF				
7.60664773D 02	1.73321192D 00	8.01156212D-01	1.09793289D 01	3.20526586D 02	5.85615758D 01	1.73578920D 00	2.10863091D 02
1.62311642D 00	5.46717287D-01	2.82055309D-01	-7.19386316D-01	2.34211885D-01	-5.36495430D-02	6.89321326D-01	4.45758554D-02
-2.21398670D 00	-2.82371423D 00	-2.92394705D-01	-7.76536382D-01	7.94824265D-01	2.33347391D 00	4.98669746D 00	3.78190322D-01
-3.46083685D 01	-9.09233716D-01	0.0	8.19396303D 01	2.49960485D 02	7.87875393D-01	4.36283857D-01	-5.32907052D-15
6.31754915D 00	-1.47183225D 02	1.46647550D 02	9.35181974D 00	1.86151637D 01	-5.32406074D 01	7.58452472D-01	7.60664773D 02
			SWITCH THRUST ON				
7.74770932D 02	1.73321192D 00	8.01156212D-01	1.09793289D 01	3.20526586D 02	6.25457622D 01	1.58179241D 00	2.14847277D 02
1.43893278D 00	6.00061093D-01	2.67331919D-01	-8.00828154D-01	2.03559385D-01	-6.82844733D-02	6.89321326D-01	5.19433865D-02
-2.44090981D 00	-2.63292145D 00	2.65095553D-01	-1.10880985D 00	7.67935493D-01	2.25144700D 00	4.98669746D 00	3.78190322D-01
-3.46083685D 01	-9.09233716D-01	0.0	8.25468033D 01	2.27240505D 02	7.87875393D-01	5.08393184D-01	0.0
1.51828676D 01	-1.56017293D 02	1.51857404D 02	9.73001255D 00	2.26370224D 01	-5.30762067D 01	8.29110924D-01	7.60664773D 02
ENCKE(1987)			END OF TRAJECTORY, THRUST ON				
8.30000000D 02	2.21700709D 00	8.48000965D-01	1.19800240D 01	3.34150129D 02	8.16415066D 01	7.88147491D-01	2.47290759D 02
4.35694708D-01	6.36512686D-01	1.61858550D-01	-1.40498588D 00	-2.80786084D-01	-1.83606684D-01	6.35350971D-01	1.10850730D-01
-4.68386251D 00	-2.65420708D 00	1.74535343D 00	-4.33064750D 00	-2.70276057D 00	-2.25197413D-01	5.51136202D 00	3.78191299D-01
-3.55209980D 01	-1.20437321D 00	0.0	8.76133882D 01	1.28152928D 02	7.89141808D-01	1.00000000D 00	1.99215292D 00
2.76580206D 01	1.50767360D 02	1.40617775D 02	1.18509142D 01	5.56982510D 01	-4.61191045D 01	1.44448522D 00	8.15893841D 02

```
CASE  1                                            ITERATOR SUMMARY

                                                INDEPENDENT PARAMETERS

  1,PRIM1(-3.2052556D-01)   2,PRIM2(-2.9421245D 00)   3,PRIM3(-8.6413568D 00)   4,PDOT1(-8.6893763D-01)   5,PDOT2( 5.1797829D-01)
  6,PDOT3( 6.3346989D-01)   7,LMASS( 1.0000000D 00)   8, LTAU( 0.0          )   9,     ( 0.0          )  10,DECLN(-4.6190001D 01)
 11,ACCEL( 4.1765371D-04)  12,V JET( 2.8439285D 04)  13,VINF1( 8.0023533D 03)  14,VINF2( 0.0          )  15,TIME1(-8.6000000D 02)
 16,TIME2(-3.0000000D 01)  17,IPARK( 0.0          )  18,VELC1( 0.0          )  19,VELD2( 0.0          )  20,VELO3( 0.0          )
 21,THET1( 0.0          )  22,THET2( 0.0          )  23,THET3( 0.0          )  24,THET4( 0.0          )  25,THET5( 0.0          )
 26,THET6( 0.0          )  27,THET7( 0.0          )  28,THET8( 0.0          )  29,THET9( 0.0          )  30,LDEGR( 0.0          )
 31, PHI1( 0.0          )  32, PHI2( 0.0          )  33, PHI3( 0.0          )  34, PHI4( 0.0          )  35, PHI5( 0.0          )
 36, PHI6( 0.0          )  37, PHI7( 0.0          )  38, PHI8( 0.0          )  39, PHI9( 0.0          )  40,PHI10( 0.0          )
 41,PR1-A(-1.1138379D 01)  42,PR2-A(-7.3151963D 00)  43,PR3-A( 1.6553991D 01)  44,PD1-A( 1.6431712D 00)  45,PD2-A(-1.1365816D 00)
 46,PD3-A(-3.7547681D 00)  47,VINFA( 0.0          )  48,TIMEA(-6.0509628D 02)  49,KSAMP( 0.0          )  50,KDROP( 0.0          )
 51,PR1-B(-3.3126336D 00)  52,PR2-B(-4.3736311D 00)  53,PR3-B(-8.0189925D 00)  54,PD1-B( 9.6128850D-01)  55,PD2-B(-1.9623345D-02)
 56,PD3-B( 1.7155384D 00)  57,VINFB( 0.0          )  58,TIMEB(-3.0930274D 02)  59,KSAMP( 0.0          )  60,KDROP( 0.0          )
 61,PR1-C( 0.0          )  62,PR2-C( 0.0          )  63,PR3-C( 0.0          )  64,PD1-C( 0.0          )  65,PD2-C( 0.0          )
 66,PD3-C( 0.0          )  67,VINFC( 0.0          )  68,TIMEC( 0.0          )  69,KSAMP( 0.0          )  70,KDROP( 0.0          )

                                                 DEPENDENT PARAMETERS

  1,DELTA X(-1.22842D-06)   2,DELTA Y(-1.28412D-06)   3,DELTA Z(-8.03121D-08)   4,DELT XD(-2.02452D-06)   5,DELT YD(-2.09683D-06)
  6,DELT ZD(-4.18634D-07)   7,       ( 0.0        )   8,       ( 0.0        )   9,       ( 0.0        )  10,T,DECLN( 3.02500D-06)
 11, POWER ( 1.00000D 01)  12,       ( 0.0        )  13,T,VINF1(-1.63911D-06)  14,       ( 0.0        )  15,       ( 0.0        )
 16,       ( 0.0        )  17,       ( 0.0        )  18,       ( 0.0        )  19,       ( 0.0        )  20,       ( 0.0        )
 21,       ( 0.0        )  22,       ( 0.0        )  23,       ( 0.0        )  24,       ( 0.0        )  25,       ( 0.0        )
 26,       ( 0.0        )  27,       ( 0.0        )  28,       ( 0.0        )  29,       ( 0.0        )  30,       ( 0.0        )
 31,       ( 0.0        )  32,       ( 0.0        )  33,       ( 0.0        )  34,       ( 0.0        )  35,       ( 0.0        )
 36,       ( 0.0        )  37,       ( 0.0        )  38,       ( 0.0        )  39,       ( 0.0        )  40,       ( 0.0        )
 41,DEL X A( 4.46709D-12)  42,DEL Y A( 4.02174D-11)  43,DEL Z A( 4.50025D-12)  44,T,PR1-A(-4.44857D-11)  45,T,PR2-A(-4.00673D-11)
 46,T,PR3-A(-1.62785D-11)  47,       ( 0.0        )  48,T,TIMEA( 5.50540D-11)  49,       ( 0.0        )  50,       ( 0.0        )
 51,DEL X B(-6.40765D-11)  52,DEL Y B( 1.16818D-10)  53,DEL Z B( 1.77209D-11)  54,T,PR1-B( 1.07260D-09)  55,T,PR2-B(-3.03183D-10)
 56,T,PR3-B(-5.32259D-10)  57,       ( 0.0        )  58,T,TIMEB( 1.32105D-10)  59,       ( 0.0        )  60,       ( 0.0        )
 61,       ( 0.0        )  62,       ( 0.0        )  63,       ( 0.0        )  64,       ( 0.0        )  65,       ( 0.0        )
 66,       ( 0.0        )  67,       ( 0.0        )  68,       ( 0.0        )  69,       ( 0.0        )  70,       ( 0.0        )

THRUST SWITCHING TIMES (DAYS)        0.0     ON     254.904 VISIT    550.697 VISIT    760.665  OFF    774.771  ON     830.000  ON

                                              ELECTRIC PROPULSION PARAMETERS
      POWER               EFFICIENCY          PROP TIME                J                PROP TIME RATIO       AVE ACCEL
   10.0000000001         0.6100000000       815.8938408641       6.8170484362        0.9830046275        0.0005239737

                                                 MASS COMPONENT BREAKDOWN
      INITIAL             PROPULSION          PROPELLANT          TANKAGE             STRUCTURE            PAYLOAD
  1027.1285815052       302.8500000043      374.5414398642      37.4541439864        0.0                  312.2829976503


SWITCH-COUNT HISTORY   ALL 8

   171 THRUST COMPUTE STEPS.     2 COAST COMPUTE STEPS

LAUNCH ASYMPTOTE OFFSET FROM PRIMER =  -48.873 DEGREES.
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION		THRUST ANGLES PSI		THRUST ANGLES THETA		THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.993		64.0		0.0	ON	8.090 00		-66.0		93.9		91.6		10.0	ON	9.6
4	11.264	13.9	MIN	0.983		74.1		0.05		7.660 00		-65.6		77.1		84.7		10.0		14.9
4	25.730	31.7	*	1.000		86.4		0.12		6.640 00		-64.7		53.2		75.2		10.0		0.0
7	71.277	78.1		1.239		131.5		0.31		3.200 00		-30.0		-34.1	MIN	44.2		7.4		0.0
4	74.155	80.3		1.260		134.7		0.32	MIN	3.180 00		-25.2		-38.0		44.5		7.2		0.0
5	103.708	99.3		1.495	MAX	155.7		0.51		4.850 00		15.2		-64.4		65.4		5.6		0.0
4	254.904	143.4		2.509		56.2		2.92	ON	1.870 01		59.2		-108.9		99.5		2.3		0.0
0	254.904	143.4		2.509		56.2		2.92	ON	1.870 01		59.2		-108.9		99.5		2.3		0.0
4	341.489	156.0		2.836	MIN	1.8		3.82		1.260 01		53.1		-108.4		100.9		1.8		0.0
5	356.670	157.9		2.875		10.1	MAX	3.84		1.140 01		50.9		-108.3		101.5		1.8		0.0
5	380.840	160.8		2.926		26.1		3.79		9.690 00		46.3	MAX	-108.3		102.5		1.7		0.0
5	462.355	165.7	MAX	3.003		85.2		2.91		5.190 00		14.2		-108.9		108.3	MIN	1.7		0.0
5	491.981	172.8		2.992		111.6		2.46	MIN	4.740 00		-4.8		-109.5		109.5		1.7		0.0
5	496.272	173.3		2.989		115.8		2.40		4.750 00		-7.7		-109.7	MAX	109.5		1.7		0.0
4	550.064	178.8		2.910	MAX	173.9		1.91		6.300 00		-39.7		-112.6		107.2		1.8		0.0
4	550.697	178.9		2.909		173.8		1.91	ON	6.330 00		-40.0		-112.6		107.2		1.8		0.0
0	550.697	178.9		2.909		173.8		1.91	ON	6.330 00		-40.0		-112.6		107.2		1.8		0.0
7	555.843	179.4		2.897		170.2	MIN	1.90		6.170 00		-39.8		-112.7		107.3		1.8		0.0
7	707.499	198.8		2.203		25.7	MAX	3.01		1.090 00		-20.4		-127.4		124.7		2.9		0.0
4	760.354	209.7		1.739	MIN	5.9		2.73		1.830-03		6.1		-147.0		146.5		4.3		0.0
5	760.665	209.7		1.736		5.9		2.73	OFF	-5.330-15		6.3		-147.2		146.6		4.4		0.0
5	767.824	211.7		1.659		6.8		2.65	MIN	-2.100-02		*****		******		*****		0.0		90.0
7	774.771	213.8		1.562		8.5		2.57	ON	0.0		15.2		-156.0		151.9		5.1		0.0
5	787.975	218.3		1.423		12.2		2.39		1.630-01		22.6		-166.3	MAX	153.7		6.0		0.0
8	814.530	232.1		1.049	MAX	16.2		1.98		1.040 00		30.0		168.0		147.9		9.4		0.0
4	815.377	232.7		1.035		16.2		1.97		1.080 00	MAX	30.0		167.1		147.6		9.6		0.0
4	817.585	234.3	*	1.000		16.1		1.93		1.190 00		30.0		164.7		146.7		10.0		0.0
4	830.000	246.7		0.788		14.0		1.73	ON	1.990 00		27.7		150.8		140.6		10.0	ON	51.6

CASE 1

MISSION SCHEDULE

MARCH 5, 1985 1.20000000D 01 G.M.T.
2446134.000D 00 JULIAN DATE — DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-9.7434701D-01	1.9166172D-01	0.0	-2.0934570D-01	-9.8500518D-01	0.0	9.9301878D-01	0.0	168.872
S/C	-9.7434701D-01	1.9166172D-01	0.0	-1.3539474D-01	-1.2187252D 00	-1.0995687D-01	9.9301878D-01	0.0	168.872

NOVEMBER 19, 1985 5.68936400D 00 G.M.T.
2446388.954D 00 JULIAN DATE — PASS INPUT TARGET AT 12.019 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	1.6812520D 00	-1.8494747D 00	-2.1854018D-01	4.0455761D-01	4.6259520D-01	-2.0500058D-02	2.5089689D 00	-4.997	-47.728
S/C	1.6812520D 00	-1.8494747D 00	-2.1854018D-01	5.1265572D-01	7.9918439D-02	4.7765784D-02	2.5089689D 00	-4.997	-47.728

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND INPUT TARGET IS 143.1084 DEGREES.

SEPTEMBR 11, 1986 4.73424014D 00 G.M.T.
2446684.697D 00 JULIAN DATE — PASS INPUT TARGET AT 10.421 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	2.8356199D 00	-6.1520935D-01	2.0358639D-01	2.4640001D-01	4.8747094D-01	1.2627182D-01	2.9087231D 00	4.014	-12.241
S/C	2.8356199D 00	-6.1520935D-01	2.0358639D-01	-6.2569062D-02	3.3118951D-01	7.6100261D-02	2.9087231D 00	4.014	-12.241

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND INPUT TARGET IS 175.8354 DEGREES.

JUNE 17, 1987 1.20000000D 01 G.M.T.
2446964.000D 00 JULIAN DATE — ARRIVE AT ENCKE(1987)

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	4.3569594D-01	6.3651397D-01	1.6185863D-01	-1.4049839D 00	-2.8078399D-01	-1.8360627D-01	7.8814922D-01	11.851	55.608
S/C	4.3569471D-01	6.3651269D-01	1.6185855D-01	-1.4049859D 00	-2.8078608D-01	-1.8360668D-01	7.8814749D-01	11.851	55.608

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND ENCKE(1987) IS 247.2607 DEGREES.

CASE 1 (CONVERGED) PERFORMANCE SUMMARY

EARTH TO ENCKE(1987) WITH FIXED ARRIVAL EXCESS SPEED

WITH VISITATIONS OF INPUT TARGET AND INPUT TARGET

ARRIVAL AT 30.000 DAYS BEFORE ENCKE(1987) PERIHELION

LAUNCH VEHICLE IS TITAN III E/CENTAUR (COEFFICIENTS = 167238.9500 3480.2038 1753.6965)

LD = MAR 9, 1985, 12.0000 HOURS GMT — JULIAN DATE 46134.0000
AD = JUN 17, 1987, 12.0000 HOURS GMT — JULIAN DATE 46964.0000
FLIGHT TIME = 830.0000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.2850	0.1000	0.0	0.61000	0.0	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
1027.1286	302.8500	374.5414	37.4541	0.0	312.2830

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
10.0000	0.0	10.0000	0.428984	4.176537D-04	2900.000	0.61000	1.00000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
3.0026235	0.7881475	10.000000	0.42898406	815.89384	231.63775	247.29076

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-46.1900	32.5000 AT LIMIT	8002.35326	64.037658	0.08770	0.000000

F. EXTRA ECLIPTIC MISSION

The objective of this mission is to place maximum payload in a circular orbit of 1.001 AU radius inclined 45 degrees to the ecliptic. The mission is $2\frac{1}{2}$ years (912.5 days) in duration and departs from Earth parking orbit on April 21, 1979. The solution given in this example is contained in the class of six-burn solutions which, for the mission duration assumed, tends to restrain the trajectory from deviating far from the nominal 1 AU solar distance. The specific case chosen uses the Titan III E/Centaur launch vehicle. The reference power (the power delivered to the power conditioners at 1 AU) is 20.35 kw and the specific impulse of the thrusters is 3000 seconds. The launch excess speed is optimized. The extra-ecliptic end conditions are invoked by setting IOUT = 1 and defining the desired values for AR, AE and AAI, the radius, eccentricity and inclination, respectively.

This case exhibits the use of several optional features of the program. A total of 0.65 kw of power developed by the solar arrays is reserved for housekeeping (non-propulsive) uses. This option is triggered with the input DPOW which is the ratio of housekeeping power to reference power. The power delivered to the power conditioners at distances below 1 AU is not permitted to exceed that delivered at 1 AU. This constraint is invoked by setting MODE equal to 5 and GAMMAX (the maximum permissible value of the power factor γ) equal to 1. The effects of launch asymptote declination are included in the launch vehicle performance model by setting LAUNCH equal to 1. The equatorial inclination of the launch parking orbit is limited to a maximum of 36 degrees through the input parameter XANG2. Since the geocentric declination of the launch asymptote for extra ecliptic missions is usually much greater than this inclination limit, the solution will include a non-coplanar injection maneuver from the launch parking orbit. The declination of the launch asymptote is optimized. Finally, the option of inputting the coefficients of the power profile is illustrated. The inputs for this case are listed on the next page.

It should be noted that the choice of final orbit radius of 1.001 AU rather than 1.0 AU was made to alleviate numerical difficulties arising as a result of the corner in the power curve at 1 AU. Neighboring trajectories terminating on opposite sides of the corner point tend to possess different partial derivatives (i.e., they will behave differently when subjected to the same perturbation). Consequently, if the final desired distance were exactly the point of the discontinuity, one might expect convergence retardation when the end conditions are nearly satisfied.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X7=1.D0,X10(2)=1.D0,X11(2)=1.D0,X12=2.941995D4
X13(2)=1.D0,X15=3.10370D1,X16=9.43537D2
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=1.D0,Y5(2)=1.D0,Y6(2)=1.D0
Y10(2)=1.D0,Y11=20.35D0,3.D0,Y13(2)=1.D0
LAUNCH=1,MBOOST=15,MTMASS=3,MODE=5
MOPT2=3,MOPT3=0,MYEAR=1979,MONTH=3,MDAY=21
BI=.63D0,DI=0.D0,CTANK=.035D0,GAMMAX=1.D0,DPOW=3.194103194103D-2
IOUT=1,AAI=45.D0,AR=1.001D0,XANG1=28.5D0,XANG2=36.D0
ASOL=1.4382D0,0.D0,-.2235D0,0.D0,-.2147D0
 X1=-1.849269016836D-02, X2=-3.444545869687D-01, X3=-5.292894680826D 00
 X4= 7.283860051662D-01, X5= 6.489958277263D-01, X6=-3.277641804973D-01
X10=-3.809150729556D 01,X11= 2.790574061256D-04,X13= 5.328606534645D 03
&END
```

CASE 1 TIME TO GO CPU 59, I/O 43 SEC

MINIMUM DENSITY = 0.0 MAXIMUM DPOWD = 1.4382000000000000D 00

PROGRAM INPJTS

X 1 = -1.8492690168360000D-02,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 = -3.4445458696870000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 = -5.2928946808260000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 = 7.2838600516620000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 = 6.4899582772630000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 = -3.2776418049730000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 = 1.0000000000000000D 00,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 = -3.8091507295560000D 01,	1.0000000000000000D 00,	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 = 2.7905740612559999D-04,	1.0000000000000000D 00,	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 = 2.9419950000000000D 04,	0.0 ,	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 = 5.3286065346449999D 03,	1.0000000000000000D 00,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 = 0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 = 3.1037000000000000D 01,	0.0 ,	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 = 9.4353700000000000D 02,	0.0 ,	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 = 0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 = 0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 = 0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 = 0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 = 0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 = 0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 = 0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 = 0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 = 0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,

X59 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X60 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X61 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X62 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X63 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X64 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X65 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X66 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X67 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X68 =	0.0	0.0	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X69 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X70 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
Y 1 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 2 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 3 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 4 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 5 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 6 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y 7 =	0.0	0.0	9.9999999999999999D-05,		
Y 8 =	0.0	0.0	9.9999999999999999D-05,		
Y 9 =	0.0	0.0	9.9999999999999999D-05,		
Y10 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y11 =	2.0350000000000000D 01,	3.0000000000000000D 00,	9.9999999999999999D-05,		
Y12 =	0.0	0.0	9.9999999999999999D-05,		
Y13 =	0.0	1.0000000000000000D 00,	9.9999999999999999D-05,		
Y14 =	0.0	0.0	9.9999999999999999D-05,		
Y15 =	0.0	0.0	9.9999999999999999D-05,		
Y16 =	0.0	0.0	9.9999999999999999D-05,		
Y17 =	0.0	0.0	9.9999999999999999D-05,		
Y18 =	0.0	0.0	9.9999999999999999D-05,		
Y19 =	0.0	0.0	9.9999999999999999D-05,		
Y20 =	0.0	0.0	9.9999999999999999D-05,		
Y21 =	0.0	0.0	9.9999999999999999D-05,		
Y22 =	0.0	0.0	9.9999999999999999D-05,		
Y23 =	0.0	0.0	9.9999999999999999D-05,		
Y24 =	0.0	0.0	9.9999999999999999D-05,		
Y25 =	0.0	0.0	9.9999999999999999D-05,		
Y26 =	0.0	0.0	9.9999999999999999D-05,		
Y27 =	0.0	0.0	9.9999999999999999D-05,		
Y28 =	0.0	0.0	9.9999999999999999D-05,		
Y29 =	0.0	0.0	9.9999999999999999D-05,		
Y30 =	0.0	0.0	9.9999999999999999D-05,		
Y31 =	0.0	0.0	9.9999999999999999D-05,		
Y32 =	0.0	0.0	9.9999999999999999D-05,		
Y33 =	0.0	0.0	9.9999999999999999D-05,		
Y34 =	0.0	0.0	9.9999999999999999D-05,		
Y35 =	0.0	0.0	9.9999999999999999D-05,		
Y36 =	0.0	0.0	9.9999999999999999D-05,		
Y37 =	0.0	0.0	9.9999999999999999D-05,		
Y38 =	0.0	0.0	9.9999999999999999D-05,		
Y39 =	0.0	0.0	9.9999999999999999D-05,		
Y40 =	0.0	0.0	9.9999999999999999D-05,		
Y41 =	0.0	0.0	9.9999999999999999D-05,		
Y42 =	0.0	0.0	9.9999999999999999D-05,		
Y43 =	0.0	0.0	9.9999999999999999D-05,		
Y44 =	0.0	0.0	9.9999999999999999D-05,		
Y45 =	0.0	0.0	9.9999999999999999D-05,		
Y46 =	0.0	0.0	9.9999999999999999D-05,		
Y47 =	0.0	0.0	9.9999999999999999D-05,		
Y48 =	0.0	0.0	9.9999999999999999D-05,		
Y49 =	0.0	0.0	9.9999999999999999D-05,		
Y50 =	0.0	0.0	9.9999999999999999D-05,		
Y51 =	0.0	0.0	9.9999999999999999D-05,		
Y52 =	0.0	0.0	9.9999999999999999D-05,		
Y53 =	0.0	0.0	9.9999999999999999D-05,		
Y54 =	0.0	0.0	9.9999999999999999D-05,		

ORIGINAL PAGE IS
OF POOR QUALITY

```
Y55 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y56 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y57 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y58 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y59 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y60 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y61 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y62 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y63 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y64 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y65 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y66 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y67 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y68 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y69 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
Y70 =  0.0                  .   0.0                   .   9.9999999999999990D-05,
&OUTPUT
AAI=  45.0000000000000   ,AE= 0.0                 ,ALPHAA=  15.0000000000000    ,ALPHAT=  15.0000000000000    ,ALTITU=
 0.0                  ,AN=  1.50000000000000    ,AR=  1.00100000000000    ,ASOL=  1.43820000000000    , 0.0
-0.223500000000000    , 0.0                  ,-0.214700000000000    ,BI= 0.630000000000000    ,B1= 0.0             ,B2=
 0.0                  ,B3= 0.0               ,CNI= 0.0                  ,CNIX= 0.0                  , 0.0
 0.0                  , 0.0                  , 0.0                 ,CSTR= 0.0                  ,CTANK= 0.34999999999999990D-01,
CTRET= 0.111111111111111    ,DI= 0.0               ,DWRETR= 0.0                  ,DPOW= 0.31941031941029990D-01,ECI=
 0.0                  ,ECIX= 0.0               , 0.0                  , 0.0                  , 0.0
 0.0                  ,EI= 0.0               ,EMUODD= 0.0                  ,EMJODX= 0.0
 0.0                  , 0.0                  , 0.0                  , 0.0                  ,GAMMAX=  1.00000000000000    ,GAP=
 0.99999999999999990D-04,HOUR=  12.0000000000000    ,OMI= 0.0                  ,OMIX= 0.0
 0.0                  , 0.0                  , 0.0                  , 0.0                  ,POWFIX= -1.00000000000000    ,
PSIGN=  1.00000000000000    ,RADODD=  1.00000000000000    ,RADODX= 0.0                  , 0.0
 0.0                  , 0.0                  , 0.0                 ,RAP=  38.0000000000000    ,REVS= 0.0
RPER=  2.00000000000000    ,SAI=  1.00000000000000    ,SAIX= 0.0                  , 0.0
 0.0                  , 0.0                  , 0.0                 ,SDI= 0.0                  ,SDIX= 0.0
 0.0                  , 0.0                  , 0.0                  , 0.0                 ,SPIRET=  300.000000000000    ,
STATE=  1.00000000000000    , 0.0                  , 0.0                  , 0.0                  , 1.00000000000000    ,
 0.0                  ,STEP1= 0.31250000000000000D-01,STEP2= 0.125000000000000    ,TCOAST= 0.0
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                 ,TDV= -1.00000000000000    ,TGO=
-1.00000000000000    ,THRET=  400.000000000000    ,TOFF= -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    , -1.00000000000000    ,
-1.00000000000000    , -1.00000000000000    ,TPI= 0.0                 ,TPIX= 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                 ,TPOWER= 0.10000000000000000D 31,TSCALE=
 1.00000000000000    ,T2=  50.0000000000000    , 100.000000000000    , 150.000000000000    , 200.000000000000    ,
 250.000000000000    , 300.000000000000    , 350.000000000000    , 400.000000000000    , 450.000000000000    ,
 500.000000000000    ,XANG1=  28.5000000000000    ,XANG2=  36.0000000000000    ,XSWING= 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                  , 0.0                  ,
 0.0                  , 0.0                  , 0.0                  , 0.0                 ,X0=  1.00000000000000    ,
 0.0                  , 0.0                  , 0.0                  , 1.00000150000000    , 0.0                  ,
 0.0                 ,IBAL=          0,INTPR=          0,IOJT=          1,IRK=          1,IRL=          1,IROT=          0,ISPIN=
        0,ITF=          3,ITPRNT=          0,JPP=          0,JPRINT=          0,JT=          0,KPART=          0,LAUNCH=
        1,LOADX=          0,MAXHAM=          5,MBDOST=         15,MDAY=         21,MODE=          5,MONTH=          3,MOPT=
        0,MOPTX=          0,          0,          0,          0,MOPT2=          3,MOPT3=          0,MOPT4=          0,
        0,          0,          0,          0,          0,          0,          0,MPOW=          0,
MPRINT=          0,MPUNCH=          0,MREAD=          0,MSWING=          0,          0,          0,          0,
        0,          0,          0,          0,MTMASS=          3,MUPDAT=          1,MYEAR=       1979,NDIST=
        3,NHUNG=         25,NORMAL=          0,NPERF=          0,NPRINT=          7,NSET=          0,          0,        300,
        0,        300,NSWING=          0,NSWPAR=          1,NTAPE=         17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	-1.8492690168360000D-02	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	-3.4445458696870000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-5.2928946808260000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	7.2838600516620000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	6.4899582772630000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	-3.2776418049730000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	10	-3.8091507295560000D 01	9.0000000000000000D 01	9.9999999999999990D-07	1.0000000000000000D 00
8	11	2.7905740612559990D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
9	13	5.3286065346449990D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	10	0.0	9.9999999999999990D-05
8	11	2.0350000000000000D 01	9.9999999999999990D-05
9	13	0.0	9.9999999999999990D-05

```
---------- NOMINAL TRAJECTORY  1 (TOTAL   1) ---------- INHIBITOR IS   5.8208D-11 ----------
                                          INDEPENDENT PARAMETERS
 1.PRIM1(-1.8492690D-02)   2.PRIM2(-3.4445459D-01)   3.PRIM3(-5.2928947D 00)   4.PDOT1( 7.2838601D-01)   5.PDOT2( 6.4899583D-01)
 6.PDOT3(-3.2776418D-01)  10.DECLN(-3.8091507D 01)  11.ACCEL( 2.7905741D-04)  13.VINF1( 5.3286065D 03)
                                           DEPENDENT PARAMETERS
 1.DELTA X( 1.36734D-02)   2.DELTA Y(-2.04257D-02)   3.DELTA Z( 2.52203D-02)   4.DELT XD( 1.62397D-02)   5.DELT YD(-2.40807D-02)
 6.DELT ZD( 2.57904D-02)  10.T.DECLN( 1.75024D-09)  11. POWER ( 2.03500D 01)  13.T.VINF1(-3.71296D-09)
THRUST SWITCHING TIMES (DAYS)       0.0     ON      80.374  OFF     103.276  ON     218.909  OFF    247.259  ON     399.777  OFF
   439.175  ON     567.999  OFF    618.895  ON     749.493  OFF     809.322  ON     912.500  ON
                                       ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME               J               PROP TIME RATIO       AVE ACCEL
   20.3499999990       0.6300000000      712.1252770929      11.3661826370          0.7804112626        0.0004309116
                                          MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT            TANKAGE              STRUCTURE            PAYLOAD
   3123.1976935923     620.2499999709     1813.3820629241       63.4683722023          0.0               626.0972584950

---------- NOMINAL TRAJECTORY  2 (TOTAL   4) ---------- INHIBITOR IS   1.8190D-12 ----------
                                          INDEPENDENT PARAMETERS
 1.PRIM1(-9.0058542D-03)   2.PRIM2(-3.5175913D-01)   3.PRIM3(-5.2008632D 00)   4.PDOT1( 6.9910970D-01)   5.PDOT2( 6.2888718D-01)
 6.PDOT3(-3.3398207D-01)  10.DECLN(-3.7843959D 01)  11.ACCEL( 2.6655743D-04)  13.VINF1( 5.1101377D 03)
                                           DEPENDENT PARAMETERS
 1.DELTA X(-1.06725D-05)   2.DELTA Y(-9.99850D-04)   3.DELTA Z(-2.51111D-03)   4.DELT XD( 1.14983D-03)   5.DELT YD(-7.22438D-04)
 6.DELT ZD( 2.13528D-03)  10.T.DECLN( 2.70967D-03)  11. POWER ( 2.03067D 01)  13.T.VINF1(-1.69061D-03)
THRUST SWITCHING TIMES (DAYS)       0.0     ON      80.395  OFF     103.651  ON     219.584  OFF    247.918  ON     400.527  OFF
   439.396  ON     566.714  OFF    616.029  ON     747.829  OFF     804.878  ON     912.500  ON
                                       ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME               J               PROP TIME RATIO       AVE ACCEL
   20.3066573251       0.6300000000      715.6762058950       9.8909155678          0.7843026914        0.0004008460
                                          MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT            TANKAGE              STRUCTURE            PAYLOAD
   3262.5709661616     618.9289536062     1819.7281211922       63.5904842417          0.0               760.2234071214

---------- NOMINAL TRAJECTORY  3 (TOTAL   7) ---------- INHIBITOR IS   5.6843D-14 ----------
                                          INDEPENDENT PARAMETERS
 1.PRIM1( 2.2736015D-03)   2.PRIM2(-3.7436282D-01)   3.PRIM3(-5.1922367D 00)   4.PDOT1( 7.0903573D-01)   5.PDOT2( 6.3603250D-01)
 6.PDOT3(-3.2226660D-01)  10.DECLN(-3.7854840D 01)  11.ACCEL( 2.6660044D-04)  13.VINF1( 5.0985903D 03)
                                           DEPENDENT PARAMETERS
 1.DELTA X( 9.71723D-04)   2.DELTA Y(-4.33226D-04)   3.DELTA Z(-1.01801D-03)   4.DELT XD(-5.13886D-04)   5.DELT YD( 4.32699D-05)
 6.DELT ZD( 3.84511D-04)  10.T.DECLN(-3.74522D-05)  11. POWER ( 2.03500D 01)  13.T.VINF1( 3.24076D-05)
THRUST SWITCHING TIMES (DAYS)       0.0     ON      80.299  OFF     103.546  ON     220.043  OFF    248.369  ON     400.927  OFF
   439.925  ON     568.200  OFF    617.759  ON     749.422  OFF     806.781  ON     912.500  ON
                                       ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY          PROP TIME               J               PROP TIME RATIO       AVE ACCEL
   20.3499746867       0.6300000000      715.0113506695       9.8704819992          0.7835740829        0.0004006508
                                          MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION          PROPELLANT            TANKAGE              STRUCTURE            PAYLOAD
   3269.1258074603     620.2492284722     1821.6164813205       63.7565768462          0.0               763.5035208214

THIS CASE IS CONVERGED.

     8 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND   3 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.
```

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
EARTH			START OF TRAJECTORY. THRUST ON.				
0.0	8.98977775D-01	1.21180874D-01	9.22842759D 00	3.09348545D 01	1.80000000D 02	1.00498235D 00	0.0
-8.62926339D-01	-5.15119079D-01	0.0	4.96430685D-01	-7.80199267D-01	-1.50185951D-01	1.00000000D 00	4.46544954D-02
1.43302209D-03	-3.71273470D-01	-5.19222332D 00	7.08559116D-01	6.35286348D-01	-3.26439161D-01	1.00000000D 00	9.49111444D-02
0.0	0.0	0.0	8.60527166D 01	1.71366591D 01	9.41156981D-01	9.93095163D-01	4.19307526D 00
-7.70840302D 01	8.06481424D 01	8.79184672D 01	0.0	-1.49165146D 02	-1.61208637D 00	9.36861858D-01	0.0
			SWITCH THRUST OFF				
8.03383162D 01	9.24015325D-01	1.03022217D-01	1.19678031D 01	4.06593345D 01	2.52732848D 02	8.89443736D-01	8.23696730D 01
3.41100615D-01	-8.02334532D-01	-1.76124469D-01	9.42332071D-01	5.25634816D-01	-4.50244954D-02	9.37112533D-01	4.79824670D-02
3.97728374D-01	-4.69486344D-02	-1.11930619D 00	-4.70177397D-02	-6.32061682D-01	5.36711351D 00	1.25303011D 00	9.49111521D-02
-3.87479887D 00	-7.30163733D-02	0.0	8.74079507D 01	1.51105162D 01	9.56142362D-01	1.00000000D 00	-3.99680289D-15
-6.04197599D 01	4.47840023D 01	6.94899910D 01	-1.14209889D 01	-6.69679493D 01	-5.51206966D 00	1.07998300D 00	8.03383162D 01
			SWITCH THRUST ON				
1.03587476D 02	9.24015325D-01	1.03022217D-01	1.19678031D 01	4.05593345D 01	2.81687783D 02	8.52502666D-01	1.11324607D 02
6.63125730D-01	-5.07008397D-01	-1.73111372D-01	6.28717705D-01	9.29830855D-01	6.25834478D-02	9.37112533D-01	4.79824670D-02
4.07327513D-01	-3.99412178D-01	1.04297296D 00	1.31127036D-01	-1.05012549D 00	5.22760591D 00	1.25303011D 00	9.49111521D-02
-3.87479887D 00	-7.30163733D-02	0.0	9.04770079D 01	1.74834324D 02	9.56142362D-01	1.00000000D 00	-1.33226763D-15
7.32179111D 01	-3.52154795D 00	7.32505352D 01	-1.17161055D 01	-3.74005722D 01	-3.91080390D 00	1.12418886D 00	8.03383162D 01
			SWITCH THRUST OFF				
2.20047131D 02	9.26812233D-01	9.30891521D-02	1.57548141D 01	4.10752060D 01	7.03114536D 01	9.29508201D-01	2.60280593D 02
-3.17352054D-01	8.40718021D-01	2.37626552D-01	-9.84539957D-01	-2.98723195D-01	1.18969743D-01	8.45914448D-01	5.31554595D-02
-2.43332572D-01	-6.42014437D-01	1.19757838D 00	-9.53083278D-01	4.97309569D-01	-4.74623336D 00	1.61188302D 00	9.49111675D-02
-8.08440714D 00	-2.04809354D-01	0.0	8.92745773D 01	1.62097586D 02	9.58530572D-01	1.00000000D 00	-1.75415238D-14
6.39873057D 01	1.08435053D 02	9.79719829D 01	1.48119626D 01	1.10680388D 02	5.33875555D 00	1.03571631D 00	1.96797972D 02
			SWITCH THRUST ON				
2.48414939D 02	9.26812233D-01	9.30891521D-02	1.57548141D 01	4.10752060D 01	9.98993508D 01	9.72918798D-01	2.89868490D 02
-7.32170229D-01	5.85470285D-01	2.60235064D-01	-6.83124837D-01	-7.13729664D-01	-2.51642405D-02	8.45914448D-01	5.31554595D-02
-5.74162417D-01	-3.78433842D-01	-1.19695974D 00	-4.74087039D-01	5.85741621D-01	-4.83344864D 00	1.61188302D 00	9.49111675D-02
-8.08440714D 00	-2.04809354D-01	0.0	8.59477730D 01	3.68564479D 01	9.58530572D-01	1.00000000D 00	2.88657986D-15
-5.84964179D 01	9.92381776D 01	9.48121931D 01	1.55142903D 01	1.41352882D 02	4.51838882D 00	9.88282761D-01	1.96797972D 02

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
			SWITCH THRUST OFF				
4.01007063D 02	9.92879243D-01	4.02155666D-02	2.21269693D 01	3.93188421D 01	2.47985770D 02	9.75885413D-01	4.36104098D 02
2.48074136D-01	-8.80159405D-01	-3.40779965D-01	9.46754478D-01	3.58787121D-01	-1.31363568D-01	7.27681725D-01	6.17920853D-02
2.35527599D-01	2.13550188D-01	-1.69256092D 00	4.52371528D-01	-1.13072380D 00	4.56849831D 00	2.33764139D 00	9.49111744D-02
-1.55912236D 01	-4.38696216D-01	0.0	9.62761537D 01	9.56648768D 00	9.95627173D-01	1.00000000D 00	-2.22044605D-16
-6.60531536D 01	4.90300110D 01	7.45660917D 01	-2.04384401D 01	-7.42594368D 01	-2.08594300D 00	1.02090603D 00	3.49390095D 02
			SWITCH THRUST ON				
4.39995224D 02	9.92879243D-01	4.02155666D-02	2.21269693D 01	3.93188421D 01	2.89061430D 02	9.56648104D-01	4.77178758D 02
7.72434893D-01	-4.50032489D-01	-3.40574061D-01	5.47287023D-01	8.75159484D-01	1.34290227D-01	7.27681725D-01	6.17920853D-02
6.06462603D-01	-7.88401037D-01	1.40586852D 00	6.78391350D-01	-1.64098079D 00	4.29290007D 00	2.33764139D 00	9.49111744D-02
-1.55912236D 01	-4.38696216D-01	0.0	1.00617913D 02	1.82708336D 02	9.95627173D-01	1.00000000D 00	-1.42108547D-14
7.68214783D 01	-2.34991726D 01	7.79316696D 01	-2.08552147D 01	-3.02257379D 01	-9.69142906D-01	1.04089436D 00	3.49390095D 02
			SWITCH THRUST OFF				
5.68192252D 02	9.88050953D-01	2.60924695D-02	2.85385054D 01	3.92753538D 01	6.34800786D 01	9.91545574D-01	6.11386147D 02
-1.50680764D-01	8.83626362D-01	4.23865999D-01	-9.46930481D-01	-2.40255093D-01	2.24854678D-01	6.27292252D-01	7.16310563D-02
2.74751786D-01	-8.12647077D-01	1.79678239D 00	-1.20802373D 00	1.53921638D 00	-3.87447795D 00	3.13515823D 00	9.49111739D-02
-2.14980782D 01	-7.14745724D-01	0.0	7.88119551D 01	1.82664697D 02	9.93669095D-01	1.00000000D 00	-1.99840144D-15
8.02170366D 01	8.96381090D 01	8.99385092D 01	2.53077453D 01	9.96773020D 01	1.48136430D 00	1.00247667D 00	4.77587122D 02
			SWITCH THRUST ON				
6.17787734D 02	9.88050953D-01	2.60924695D-02	2.85385064D 01	3.92753538D 01	1.11915500D 02	1.00964716D 00	6.59821569D 02
-8.12635205D-01	3.98440091D-01	4.47500736D-01	-5.13813741D-01	-8.22276169D-01	-1.69274393D-01	6.27292252D-01	7.07254966D-02
-7.59651492D-01	6.68759640D-01	-1.71464309D 00	-1.11335732D 00	1.73741786D 00	-3.83105002D 00	3.13515823D 00	9.49111739D-02
-2.14980782D 01	-7.14745724D-01	0.0	7.33252191D 01	3.48989604D 00	9.93669095D-01	9.86669286D-01	0.0
-8.49679201D 01	4.86568434D 01	8.66783836D 01	2.63098225D 01	1.53881000D 02	8.16706132D-01	9.84274595D-01	4.77587122D 02
			SWITCH THRUST OFF				
7.49620995D 02	1.00804875D 00	1.32228657D-02	3.66979141D 01	3.85848967D 01	2.39910774D 02	9.98897052D-01	7.86976106D 02
4.07334674D-02	-8.54029807D-01	-5.16497041D-01	9.31329097D-01	2.34806476D-01	-2.96115285D-01	5.25445504D-01	8.55749471D-02
-6.46199962D-01	8.69900643D-01	-2.03255295D 00	1.22009578D 00	-1.96700217D 00	3.54678452D 00	4.32996125D 00	9.49111731D-02
-2.83589344D 01	-1.09577048D 00	0.0	1.07234215D 02	3.47675472D 02	1.00392853D 00	1.00000000D 00	-1.33226763D-15
-8.13025878D 01	3.62548364D 01	8.29959259D 01	-3.11357392D 01	-8.72693126D 01	-5.50853847D-01	1.00508349D 00	6.09420384D 02

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANG_E	VMAG	PROP TIME

SWITCH THRUST ON

8.069674900D 02	1.008048750D 00	1.322286570D-02	3.66979141D 01	3.858489670D 01	2.971215400D 02	9.949174200D-01	8.441868720D 02
7.973548400D-01	-2.721259110D-01	-5.291818420D-01	4.73837759D-01	8.478079300D-01	2.736805820D-01	5.254455040D-01	8.557494710D-02
7.835617570D-01	-1.429434320D 00	1.627366430D 00	1.50229447D 00	-2.195337040D 00	3.286782330D 00	4.329961250D 00	9.491117310D-02
-2.835893440D 01	-1.095770480D 00	0.0	1.13591407D 02	1.956872790D 02	1.003928530D 00	1.000000000D 00	-2.220446050D-16
7.946959820D 01	-6.863345320D 01	8.618216410D 01	-3.21329183D 01	-1.384404610D 01	1.300956420D-01	1.009059750D 00	6.094203840D 02

INPUT TARGET

END OF TRAJECTORY, THRUST ON

9.125000000D 02	1.001065380D 00	9.482929380D-05	4.49997836D 01	3.576237590D 01	4.278717760D 01	1.000974630D 00	9.482619080D 02
3.007513090D-01	8.248284640D-01	4.807877500D-01	-8.54397579D-01	9.158705550D-03	5.186863550D-01	4.428474530D-01	1.013985430D-01
1.219411480D 00	-1.874468100D 00	2.728663000D 00	-1.26430491D 00	1.820503340D 00	-2.369610530D 00	5.782196730D 00	9.491117590D-02
-3.470770810D 01	-1.512366970D 00	0.0	7.32087472D 01	2.021395460D 02	1.000532540D 00	9.986459540D-01	9.355199940D-01
8.381241470D 01	6.962279920D 01	8.784916900D 01	2.87062738D 01	6.996698860D 01	-1.594932950D-03	9.995583450D-01	7.149528940D 02

```
CASE 1                                         ITERATOR SUMMARY

                                          INDEPENDENT PARAMETERS

 1,PRIM1( 1.4330221D-03)  2,PRIM2(-3.7127347D-01)  3,PRIM3(-5.1922233D 00)  4,PDOT1( 7.0855915D-01)  5,PDOT2( 6.3528635D-01)
 6,PDOT3(-3.2643916D-01)  7,LMASS( 1.0000000D 00)  8, LTAJ( 0.0          )  9,     ( 0.0          ) 10,DECLN(-3.7853674D 01)
11,ACCEL( 2.6664805D-04) 12,V JET( 2.9419950D 04) 13,VINF1( 5.0995285D 03) 14,VINF2( 0.0          ) 15,TIME1( 3.1037000D 01)
16,TIME2( 9.4353700D 02) 17,IPARK( 0.0          ) 18,VEL01( 0.0          ) 19,VEL02( 0.0          ) 20,VEL03( 0.0          )
21,THET1( 0.0          ) 22,THET2( 0.0          ) 23,THET3( 0.0          ) 24,THET4( 0.0          ) 25,THET5( 0.0          )
26,THET6( 0.0          ) 27,THET7( 0.0          ) 28,THET8( 0.0          ) 29,THET9( 0.0          ) 30,LDEGR( 0.0          )
31, PHI1( 0.0          ) 32, PHI2( 0.0          ) 33, PHI3( 0.0          ) 34, PHI4( 0.0          ) 35, PHI5( 0.0          )
36, PHI6( 0.0          ) 37, PHI7( 0.0          ) 38, PHI8( 0.0          ) 39, PHI9( 0.0          ) 40,PHI10( 0.0          )
41,PR1-A( 0.0          ) 42,PR2-A( 0.0          ) 43,PR3-A( 0.0          ) 44,PD1-A( 0.0          ) 45,PD2-A( 0.0          )
46,PD3-A( 0.0          ) 47,VINFA( 0.0          ) 48,TIMEA( 0.0          ) 49,KSAMP( 0.0          ) 50,KDROP( 0.0          )
51,PR1-B( 0.0          ) 52,PR2-B( 0.0          ) 53,PR3-B( 0.0          ) 54,PD1-B( 0.0          ) 55,PD2-B( 0.0          )
56,PD3-B( 0.0          ) 57,VINFB( 0.0          ) 58,TIMEB( 0.0          ) 59,KSAMP( 0.0          ) 60,KDROP( 0.0          )
61,PR1-C( 0.0          ) 62,PR2-C( 0.0          ) 63,PR3-C( 0.0          ) 64,PD1-C( 0.0          ) 65,PD2-C( 0.0          )
66,PD3-C( 0.0          ) 67,VINFC( 0.0          ) 68,TIMEC( 0.0          ) 69,KSAMP( 0.0          ) 70,KDROP( 0.0          )

                                           DEPENDENT PARAMETERS

 1,DELTA X( 3.62559D-05)  2,DELTA Y(-1.85804D-05)  3,DELTA Z(-4.36244D-05)  4,DELT XD(-4.20018D-05)  5,DELT YD( 2.21776D-05)
 6,DELT ZD( 4.21362D-05)  7,       ( 0.0        )  8,       ( 0.0        )  9,       ( 0.0        ) 10,T.DECLN( 5.77598D-07)
11, POWER ( 2.03500D 01) 12,       ( 0.0        ) 13,T.VINF1(-1.61358D-06) 14,       ( 0.0        ) 15,       ( 0.0        )
16,       ( 0.0        ) 17,       ( 0.0        ) 18,       ( 0.0        ) 19,       ( 0.0        ) 20,       ( 0.0        )
21,       ( 0.0        ) 22,       ( 0.0        ) 23,       ( 0.0        ) 24,       ( 0.0        ) 25,       ( 0.0        )
26,       ( 0.0        ) 27,       ( 0.0        ) 28,       ( 0.0        ) 29,       ( 0.0        ) 30,       ( 0.0        )
31,       ( 0.0        ) 32,       ( 0.0        ) 33,       ( 0.0        ) 34,       ( 0.0        ) 35,       ( 0.0        )
36,       ( 0.0        ) 37,       ( 0.0        ) 38,       ( 0.0        ) 39,       ( 0.0        ) 40,       ( 0.0        )
41,       ( 0.0        ) 42,       ( 0.0        ) 43,       ( 0.0        ) 44,       ( 0.0        ) 45,       ( 0.0        )
46,       ( 0.0        ) 47,       ( 0.0        ) 48,       ( 0.0        ) 49,       ( 0.0        ) 50,       ( 0.0        )
51,       ( 0.0        ) 52,       ( 0.0        ) 53,       ( 0.0        ) 54,       ( 0.0        ) 55,       ( 0.0        )
56,       ( 0.0        ) 57,       ( 0.0        ) 58,       ( 0.0        ) 59,       ( 0.0        ) 60,       ( 0.0        )
61,       ( 0.0        ) 62,       ( 0.0        ) 63,       ( 0.0        ) 64,       ( 0.0        ) 65,       ( 0.0        )
66,       ( 0.0        ) 67,       ( 0.0        ) 68,       ( 0.0        ) 69,       ( 0.0        ) 70,       ( 0.0        )

THRUST SWITCHING TIMES (DAYS)          0.0    ON       80.338  OFF     103.587  ON      220.047  OFF     248.415  ON      401.007  OFF
   439.995  ON      568.192  OFF     617.788  ON      749.621  OFF     806.967  ON      912.530  ON

                                      ELECTRIC PROPULSION PARAMETERS
    POWER              EFFICIENCY        PROP TIME              J                PROP TIME RATIO       AVE ACCEL
    20.3499990796      0.6300000000      714.9528938345         9.8696171166      0.7835100206          0.0004006926

                                         MASS COMPONENT BREAKDOWN
    INITIAL            PROPULSION        PROPELLANT             TANKAGE           STRUCTURE             PAYLOAD
   3268.5460092059     620.2499719473    1821.0787330785        63.7377556577      0.0                  763.4795485224


SWITCH-COUNT HISTORY   ALL 12

   422 THRUST COMPUTE STEPS.     32 COAST COMPUTE STEPS

LAUNCH ASYMPTOTE OFFSET FROM PRIMER =  -32.786 DEGREES.
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION		THRUST ANGLES PSI		THRUST ANGLES THETA		THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		1.005		75.7		0.0	ON	4.19D 00		-77.1		80.5		87.9		20.2	ON	0.0
4	1.065	1.0		1.004		75.3		0.00	MAX	4.19D 00		-77.1		80.5		87.9		20.2		0.0
5	8.379	7.6	*	1.000		72.6		0.03		4.15D 00		-77.2		79.6		87.7		20.3		0.0
4	8.428	7.7		1.000		72.5		0.03		4.13D 00	MIN	-77.2		79.6		87.7	MAX	20.3		0.7
4	80.338	82.2		0.889		52.3		0.24	OFF	-4.00D-15		-60.4		44.8		69.5		20.3		37.7
6	91.933	96.6		0.870		51.4		0.28	MIN	-7.45D-01		*****		******		*****		0.0		90.0
7	99.677	106.6		0.858	MIN	51.3		0.31		-3.29D-01		*****		******		*****		0.0		90.0
5	103.587	111.8		0.853		51.3		0.32	ON	-1.33D-15		73.2		-3.5		73.3		20.3		43.4
4	136.984	156.9	MIN	0.830		54.2		0.45		2.39D 00		85.4		-80.5		89.2		20.3		46.5
4	159.653	186.8		0.840		57.0		0.55	MAX	2.93D 00		87.2		-133.4		91.9		20.3		45.1
5	165.388	194.2		0.846		57.6		0.57		2.90D 00	MAX	87.3		-154.1		92.4		20.3		44.4
4	220.047	259.8		0.930		62.3		0.78	OFF	-1.75D-14		64.0		108.4		98.0		20.3		30.2
8	234.249	275.5		0.952		63.3		0.81	MIN	-7.08D-01		*****		******		*****		0.0		90.0
5	248.415	290.5		0.973		64.5		0.82	ON	2.39D-15		-58.5		99.2		94.8		20.3		18.8
4	257.189	299.5		0.984		65.3	MAX	0.82		6.50D-01		-68.1		97.2		92.7		20.3		14.5
4	272.871	314.9	*	1.000		66.7		0.82		1.74D 00		-74.7		93.7		91.0		20.3		0.0
5	315.465	353.8		1.019		70.4		0.74		3.17D 00	MIN	-78.1		84.3		88.8		19.9		0.0
4	316.969	355.2	MAX	1.019		70.5		0.74		3.49D 00		-78.1		84.0		88.8	MIN	19.8		0.0
5	325.138	362.3		1.018		70.9		0.72	MAX	3.53D 00		-78.0		82.1		88.4		19.8		0.0
4	335.882	371.8		1.016	MAX	71.1		0.70		3.15D 00		-77.7		79.5		87.8		19.9		0.0
4	356.876	390.7		1.006		70.3	MIN	0.59		2.84D 00		-76.5		73.6		86.2		20.2		0.0
3	366.544	399.8	*	1.000		69.5		0.59		2.38D 00		-75.6		70.3		85.2		20.3		0.0
6	401.007	434.9		0.976		65.2		0.75	OFF	-2.22D-16		-66.1		49.0		74.6		20.3		17.8
6	420.432	456.6		0.965		62.8		0.80	MIN	-1.24D 00		*****		******		*****		0.0		90.0
5	439.995	478.9		0.957		61.1		0.84	ON	-1.42D-14		76.8		-23.5		77.9		20.3		23.8
4	461.762	503.1	MIN	0.953		60.2		0.87		1.52D 00		83.1		-60.5		86.6		20.3		24.6
4	467.030	508.7		0.954	MIN	60.2		0.87		1.31D 00		83.8		-67.2		87.6		20.3		24.6
5	476.946	518.9		0.955		60.3	MAX	0.87		2.27D 00		84.9		-78.6		89.0		20.3		24.3
4	503.064	544.6		0.962		61.2		0.87	MAX	2.79D 00		87.6		-115.0		91.0		20.3		22.2
6	509.882	551.0		0.965		61.5	MIN	0.87		2.75D 00		88.1		-133.9		91.3		20.3		21.4
5	518.520	559.2		0.969		61.8		0.87		2.51D 00	MAX	88.5		-172.2		91.5		20.3		20.3
4	529.847	570.1		0.974		62.1		0.87		2.25D 00		87.8		139.0	MAX	91.6		20.3		18.5
4	544.170	584.0		0.980	MAX	62.3		0.89		1.53D 00		86.0		111.0		91.4		20.3		16.0
4	568.192	608.8		0.992		61.9		0.94	OFF	-2.00D-15		80.2		89.6		89.9		20.3		10.5
5	588.100	630.6	*	1.000		61.3		0.97		-1.51D 00		*****		******		*****		0.0		90.0
6	593.002	636.1		1.002		61.2		0.98	MIN	-1.72D 00		*****		******		*****		0.0		90.0
5	604.245	648.5		1.006	MIN	61.1		0.99		-1.04D 00		*****		******		*****		0.0		90.0
5	613.892	658.9		1.009		61.2	MAX	1.00		-2.92D-01		*****		******		*****		0.0		90.0
6	617.788	663.0		1.010		61.3		1.00	ON	0.0		-85.0		48.7		86.7		20.1		0.0
5	633.894	679.4		1.013		62.1		0.98		1.10D 00		-87.1	MIN	42.5		87.9		20.0		0.0
5	651.984	696.2		1.015		63.6		0.94		2.04D 00	MIN	-87.6		48.8		88.4		19.9		0.0
4	658.478	701.9	MAX	1.015		64.3		0.92		2.28D 00		-87.6		52.6		88.5	MIN	19.9		0.0
4	668.726	710.5		1.014		65.4		0.88		2.56D 00		-87.4		57.8	MAX	88.6		19.9		0.0
6	683.476	722.6		1.013		66.8		0.83	MAX	2.71D 00		-86.8		62.1		88.5		20.0		0.0
7	692.955	730.2		1.011		67.4		0.81		2.65D 00		-86.3	MAX	62.8		88.3		20.0		0.0
4	704.384	739.6		1.009	MAX	67.7		0.79		2.41D 00		-85.6		61.9		87.9		20.1		0.0
6	711.876	745.9		1.007		67.6	MIN	0.78		2.15D 00		-85.1		60.3		87.6		20.1		0.0
4	743.566	775.5	*	1.000		64.5		0.85		4.29D-01		-82.3		42.9		84.3		20.3		0.0
4	749.621	781.9		0.999		63.6		0.87	OFF	-1.33D-15		-81.3		36.3		83.0		20.3		3.8
6	778.265	815.8		0.995		59.6		0.99	MIN	-2.00D 00		*****		******		*****		0.0		90.0
5	796.948	838.7	MIN	0.995		58.1		1.03		-7.51D-01		*****		******		*****		0.0		90.0
6	806.967	850.3		0.995		57.8		1.04	ON	-2.22D-16		79.5		-68.5		86.2		20.3		8.2
5	809.171	852.8		0.995	MIN	57.8		1.04		1.57D-01		80.1		-70.6		86.7		20.3		8.1
4	810.095	853.8		0.995		57.8	MAX	1.04		2.22D-01		80.3		-71.4		86.9		20.3		8.0
4	857.824	896.6		1.000		62.1		0.92		2.29D 00		88.4		-116.9	MAX	90.7		20.3		2.3
5	863.133	900.6	*	1.000		62.8		0.90		2.33D 00		89.1		-136.6		90.7		20.3		0.0
4	866.463	903.1		1.000		63.3		0.89	MAX	2.34D 00		89.4		-165.0		90.6		20.3		0.0
5	868.262	904.4		1.000		63.5		0.88		2.34D 00	MAX	89.4		171.9		90.6		20.3		0.0
6	895.587	924.9		1.001		65.7	MIN	0.82		1.75D 00		86.2		81.6		89.5		20.3		0.0
5	896.651	925.8	MAX	1.001		65.7		0.83		1.71D 00		86.1		80.8		89.4	MIN	20.3		0.0
4	898.104	926.9		1.001	MAX	65.7		0.83		1.55D 00		85.9		79.8		89.3		20.3		0.0
5	912.500	939.1		1.001		65.1		0.85	ON	9.35D-01		83.8		69.6		87.8		20.3	ON	0.0

MISSION SCHEDULE

APRIL 21, 1979 1.2888000D 01 G.M.T.
2443985.037D 00 JULIAN DATE

DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-8.6292634D-01	-5.1511908D-01	0.0	4.9631842D-01	-8.6241113D-01	0.0	1.0049824D 00	0.0	-149.165
S/C	-8.6292634D-01	-5.1511908D-01	0.0	4.9543063D-01	-7.8019927D-01	-1.5018595D-01	1.0049824D 00	0.0	-149.165

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

OUT OF ECLIPTIC MISSION FINAL INCLINATION = 44.9998 DEG

LAUNCH VEHICLE IS TITAN III E/CENTAUR (COEFFICIENTS = 157238.9500 3480.2038 1753.6965)

LD = APR 21, 1979, 12.8880 HOURS GMT
JULIAN DATE 43985.0370

AD = OCT 20, 1981, 0.8880 HOURS GMT
JULIAN DATE 44897.5370

FLIGHT TIME = 912.5000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.0000	0.0350	0.0	0.63000	0.0	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
3268.5460	620.2500	1821.0737	63.7378	0.0	763.4795

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
20.3500	0.6500	20.3224	0.871551	2.6664800D-04	3000.000	0.63000	1.0000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
1.0189599	0.8296067	20.349999	0.37155141	714.95289	710.01587	948.26191

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-37.8537	36.0000 AT LIMIT	5099.62849	26.006211	0.0	0.0

G. COMET RENDEZVOUS MISSION

The objective of this mission is to deliver maximum payload to the comet Tempel II, rendezvousing at perihelion of the comet's path in the 1988 apparition. For the case shown, the arrival date is fixed at September 16, 1988; the launch date and launch excess speed are optimized to yield maximum payload for the nominally 4-year class of solutions. The launch vehicle assumed is the Titan III E/Centaur. The electric propulsion system parameters are representative of projections of the SERT III spacecraft. Specifically, the reference power is 8.671 kw, the specific impulse is 2900 seconds, the efficiency is 0.63376 and the specific propulsion system mass (arrays plus power conditioning and thruster subsystem) is 30.285 kg/kw.

This example illustrates the use of the solar array degradation option. This option is invoked by setting the characteristic degradation time TPOWER to a value less than 10^{10}. In this case, it is set to 7121* days which means that if the arrays were situated at 1 AU and oriented normal to the sun line for this amount of time, the power developed by the array would degrade to 1/e of its initial power output. The input MPOW = 1 forces the arrays to be oriented normal to the sun line throughout the mission. Setting the triggers X30(2) and Y30(2) to 1 results in the optimal adjustment of the trajectory to accomodate the degradation. The complete set of inputs for this case follows and the resultant program output begins on the next page.

```
&MINPUT X1(2)=1.D0,X2(2)=1.D0,X3(2)=1.D0,X4(2)=1.D0,X5(2)=1.D0
X6(2)=1.D0,X11(2)=1.D0,X13(2)=1.D0,X15(2)=1.D0,X7=1.D0
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y4(2)=1.D0,Y5(2)=1.D0,Y6(2)=1.D0
Y13(2)=1.D0,Y15(2)=1.D0,ALPHAT=15.285D0,MBOOST=15,MTMASS=3
MOPT2=3,MOPT3=43,MYEAR=1988,MONTH=9,MDAY=16,HOUR=17.22D0
X12=2.8439285D4,BI=.63376D0,DI=0.D0,CTANK=.1D0,Y11=8.671D0,3.D0,1.D-3
TPOWER=7121.D0,MPOW=1,X30(2)=1.D0,Y30(2)=1.D0
 X1= 5.07299858822D 00, X2= 3.350183672126D 00, X3=-2.159808142389D 00
 X4=-2.069314933312D 00, X5= 4.565247741305D 00, X6= 3.317322088503D-01
X11= 1.647979654151D-04,X13= 6.718039798493D 03,X15=-1.517625284470D 03
X30=-4.657406222646D-03 &END
```

*Corresponds to 5% degradation per year.

CASE 1 TIME TO GO CPU 59, I/D 43 SEC

PROGRAM INPUTS

X 1 =	5.0729985882240000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 =	3.3501836721260000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 =	-2.1598081423890000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 =	-2.0693149333120000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 =	4.5652477413050000D 00,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 =	3.3173220885030000D-01,	1.0000000000000000D 00,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 =	1.0000000000000000D 00,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 =	0.0 ,	0.0 ,	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 =	1.6479796541510000D-04,	1.0000000000000000D 00,	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 =	2.8439285000000000D 04,	0.0 ,	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 =	6.7180397984929999D 03,	1.0000000000000000D 00,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 =	-1.5176252844700000D 03,	1.0000000000000000D 00,	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 =	0.0 ,	0.0 ,	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 =	0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 =	0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 =	0.0 ,	0.0 ,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 =	-4.6574062226459999D-03,	1.0000000000000000D 00,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 =	0.0 ,	0.0 ,	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 =	0.0 ,	0.0 ,	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 =	0.0 ,	0.0 ,	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X59 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X60 =	0.0 ,	0.0 ,	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,

ORIGINAL PAGE IS OF POOR QUALITY

X61 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X62 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X63 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X64 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X65 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X66 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X67 =	0.0	0.0	5.0000000000000000D 02	9.9999999999999999D-05	1.0000000000000000D 00
X68 =	0.0	0.0	5.0000000000000000D 01	9.9999999999999999D-07	1.0000000000000000D 00
X69 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
X70 =	0.0	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
Y 1 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y 2 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y 3 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y 4 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y 5 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y 6 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y 7 =	0.0	0.0	9.9999999999999999D-05		
Y 8 =	0.0	0.0	9.9999999999999999D-05		
Y 9 =	0.0	0.0	9.9999999999999999D-05		
Y10 =	0.0	0.0	9.9999999999999999D-05		
Y11 =	8.6710000000000000D 00	3.0000000000000000D 00	9.9999999999999999D-04		
Y12 =	0.0	0.0	9.9999999999999999D-05		
Y13 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y14 =	0.0	0.0	9.9999999999999999D-05		
Y15 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y16 =	0.0	0.0	9.9999999999999999D-05		
Y17 =	0.0	0.0	9.9999999999999999D-05		
Y18 =	0.0	0.0	9.9999999999999999D-05		
Y19 =	0.0	0.0	9.9999999999999999D-05		
Y20 =	0.0	0.0	9.9999999999999999D-05		
Y21 =	0.0	0.0	9.9999999999999999D-05		
Y22 =	0.0	0.0	9.9999999999999999D-05		
Y23 =	0.0	0.0	9.9999999999999999D-05		
Y24 =	0.0	0.0	9.9999999999999999D-05		
Y25 =	0.0	0.0	9.9999999999999999D-05		
Y26 =	0.0	0.0	9.9999999999999999D-05		
Y27 =	0.0	0.0	9.9999999999999999D-05		
Y28 =	0.0	0.0	9.9999999999999999D-05		
Y29 =	0.0	0.0	9.9999999999999999D-05		
Y30 =	0.0	1.0000000000000000D 00	9.9999999999999999D-05		
Y31 =	0.0	0.0	9.9999999999999999D-05		
Y32 =	0.0	0.0	9.9999999999999999D-05		
Y33 =	0.0	0.0	9.9999999999999999D-05		
Y34 =	0.0	0.0	9.9999999999999999D-05		
Y35 =	0.0	0.0	9.9999999999999999D-05		
Y36 =	0.0	0.0	9.9999999999999999D-05		
Y37 =	0.0	0.0	9.9999999999999999D-05		
Y38 =	0.0	0.0	9.9999999999999999D-05		
Y39 =	0.0	0.0	9.9999999999999999D-05		
Y40 =	0.0	0.0	9.9999999999999999D-05		
Y41 =	0.0	0.0	9.9999999999999999D-05		
Y42 =	0.0	0.0	9.9999999999999999D-05		
Y43 =	0.0	0.0	9.9999999999999999D-05		
Y44 =	0.0	0.0	9.9999999999999999D-05		
Y45 =	0.0	0.0	9.9999999999999999D-05		
Y46 =	0.0	0.0	9.9999999999999999D-05		
Y47 =	0.0	0.0	9.9999999999999999D-05		
Y48 =	0.0	0.0	9.9999999999999999D-05		
Y49 =	0.0	0.0	9.9999999999999999D-05		
Y50 =	0.0	0.0	9.9999999999999999D-05		
Y51 =	0.0	0.0	9.9999999999999999D-05		
Y52 =	0.0	0.0	9.9999999999999999D-05		
Y53 =	0.0	0.0	9.9999999999999999D-05		
Y54 =	0.0	0.0	9.9999999999999999D-05		
Y55 =	0.0	0.0	9.9999999999999999D-05		
Y56 =	0.0	0.0	9.9999999999999999D-05		

```
Y57 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y58 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y59 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y60 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y61 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y62 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y63 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y64 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y65 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y66 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y67 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y68 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y69 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
Y70 =  0.0                   ,  0.0                 ,  9.999999999999999D-05,
&OUTPUT
AAI= 0.0                  ,AE= 0.0                ,ALPHAA=  15.00000000000000    ,ALPHAT=  15.28500000000000    ,ALTITU=
 0.0                 ,AN=  1.500000000000000    ,AR=  1.000000000000000    ,ASOL= 0.0               , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 ,BI= 0.6337600000000000    ,B1= 0.0             ,B2=
 0.0                 ,B3= 0.0              ,CNI= 0.0             ,CNIX= 0.0            , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 ,CSTR= 0.0            ,CTANK= 0.1000000000000000D 00,
CTRET= 0.1111111111111111    ,DI= 0.0              ,DMRETR= 0.0              ,DPOW= 0.0              ,ECI=
 0.0                 ,ECIX= 0.0            , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 ,EI= 0.0              ,EMUDDD= 0.0          ,EMUDDX= 0.0          ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 ,GAMMAX=  1.000000000000000    ,GAP=
 0.9999999999999999D-04,HOUR=  17.22000000000000    ,OMI= 0.0            ,OMIX= 0.0            ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 ,POWFIX= -1.000000000000000    ,
PSIGN=  1.000000000000000    ,RADDDD=  1.000000000000000    ,RADDDX= 0.0          , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 ,RAP=  38.00000000000000    ,REVS= 0.0          ,
RPER=  2.000000000000000    ,SAI=  1.000000000000000    ,SAIX= 0.0          , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 ,SOI= 0.0             ,SOIX= 0.0            ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 ,SPIRET=  300.0000000000000    ,
STATE=  1.000000000000000    , 0.0                 , 0.0                 , 0.0                 ,  1.000000000000000    ,
 0.0                 ,STEP1= 0.3125000000000000D-01,STEP2= 0.1250000000000000    ,TCOAST= 0.0              ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 ,TDV= -1.000000000000000    ,TGO=
 -1.000000000000000    ,THRET=  400.0000000000000    ,TOFF= -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
 -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
 -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
 -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    , -1.000000000000000    ,
 -1.000000000000000    , -1.000000000000000    ,TPI= 0.0             ,TPIX= 0.0            , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 ,TPOWER=  7121.000000000000    ,TSCALE=
  1.000000000000000    ,T2=  50.00000000000000    ,  100.0000000000000    ,  150.0000000000000    ,  200.0000000000000    ,
  250.0000000000000    ,  300.0000000000000    ,  350.0000000000000    ,  400.0000000000000    ,  450.0000000000000    ,
  500.0000000000000    ,XANG1= 0.0          ,XANG2=  32.50000000000000    ,XSWING= 0.0          ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 , 0.0                 ,
 0.0                 , 0.0                 , 0.0                 , 0.0                 ,X0=  1.000000000000000    ,
 0.0                 , 0.0                 , 0.0                 ,  1.000001500000000    , 0.0                 ,
 0.0                 ,IBAL=          0,INTPR=          0,IOUT=          0,IRK=          1,IRL=          1,IROT=          0,ISPIN=
        0,ITF=          3,ITPRNT=          0,JPP=          0,JPRINT=          0,JT=          0,KPART=          0,LAUNCH=
        0,LOADX=          0,MAXHAM=          5,MBOOST=          15,MDAY=          16,MODE=          4,MONTH=          9,MOPT=
        0,MOPTX=          0,          0,          0,          0,          0,MOPT2=          3,MOPT3=          43,MOPT4=          0,
        0,          0,          0,          0,          0,          0,          0,          0,MPOW=          1,
MPRINT=          0,MPUNCH=          0,MREAD=          0,MSWING=          0,          0,          0,          0,          0,
        0,          0,          0,          0,MTMASS=          3,MUPDAT=          1,MYEAR=          1988,NDIST=
        3,NHUNG=          25,NORMAL=          0,NPERF=          0,NPRINT=          7,NSET=          0,          0,          300,
        0,          300,NSWING=          0,NSWPAR=          1,NTAPE=          17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	1	5.0729985882240000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
2	2	3.3501836721260000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
3	3	-2.1598081423890000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
4	4	-2.0693149333120000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	5	4.5652477413050000D 00	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	6	3.3173220885030000D-01	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
7	11	1.6479796541510000D-04	9.9999999999999990D-04	1.0000000000000000D-11	1.0000000000000000D 00
8	13	6.7180397984929990D 03	5.0000000000000000D 02	9.9999999999999990D-05	1.0000000000000000D 00
9	15	-1.5176252844700000D 03	8.0000000000000000D 00	9.9999999999999990D-07	1.0000000000000000D 00
10	30	-4.6574062226459990D-03	1.0000000000000000D 01	9.9999999999999990D-05	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	4	0.0	9.9999999999999990D-05
5	5	0.0	9.9999999999999990D-05
6	6	0.0	9.9999999999999990D-05
7	11	8.6710000000000000D 00	9.9999999999999990D-04
8	13	0.0	9.9999999999999990D-05
9	15	0.0	9.9999999999999990D-05
10	30	0.0	9.9999999999999990D-05

```
---------- NOMINAL TRAJECTORY  1 (TOTAL   1) ---------- INHIBITOR IS   5.8208D-11 ----------
                                        INDEPENDENT PARAMETERS
 1,PRIM1( 5.0729986D 00)  2,PRIM2( 3.3501837D 00)  3,PRIM3(-2.1595081D 00)  4,PDOT1(-2.0693149D 00)  5,PDOT2( 4.5652477D 00)
 6,PDOT3( 3.3173221D-01) 11,ACCEL( 1.6479797D-04) 13,VINF1( 6.7180398D 03) 15,TIME1(-1.5176253D 03) 30,LDEGR(-4.6574062D-03)
                                        DEPENDENT PARAMETERS
 1,DELTA X(-8.888980D-02)  2,DELTA Y( 3.210130D-01)  3,DELTA Z(-1.568970D-03)  4,DELT XD(-1.140630D-01)  5,DELT YD( 2.328850D-01)
 6,DELT ZD( 5.616280D-03) 11, POWER ( 8.671000D 00) 13,T,VINF1(-4.416450D-02) 15,T,TIME1( 3.361960D-06) 30,T,DEGRD( 2.325040D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1517.625  ON
                                      ELECTRIC PROPULSION PARAMETERS
    POWER            EFFICIENCY          PROP TIME              J              PROP TIME RATIO       AVE ACCEL
  8.6710000109       0.6337600000      1517.6252844700      1.0915980627        1.0000000000        0.0001829860
                                        MASS COMPONENT BREAKDOWN
    INITIAL           PROPULSION          PROPELLANT          TANKAGE             STRUCTURE            PAYLOAD
  2345.0574592971    262.6012353301     443.0100468725      44.3010046873         0.0             1595.1451724072

---------- NOMINAL TRAJECTORY  2 (TOTAL   6) ---------- INHIBITOR IS   5.9605D-08 ----------
                                        INDEPENDENT PARAMETERS
 1,PRIM1( 5.3132693D 00)  2,PRIM2( 3.3270277D 00)  3,PRIM3(-2.1717152D 00)  4,PDOT1(-2.0698180D 00)  5,PDOT2( 4.7839810D 00)
 6,PDOT3( 3.1881327D-01) 11,ACCEL( 1.6287355D-04) 13,VINF1( 6.6779946D 03) 15,TIME1(-1.5192051D 03) 30,LDEGR(-2.8739127D-03)
                                        DEPENDENT PARAMETERS
 1,DELTA X( 2.528050D-01)  2,DELTA Y( 3.105510D-02)  3,DELTA Z(-3.775410D-02)  4,DELT XD(-4.176470D-02)  5,DELT YD(-1.357670D-03)
 6,DELT ZD( 4.368550D-02) 11, POWER ( 8.659520D 00) 13,T,VINF1(-7.253690D-02) 15,T,TIME1( 4.724890D-03) 30,T,DEGRD( 3.867910D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1519.205  ON
                                      ELECTRIC PROPULSION PARAMETERS
    POWER            EFFICIENCY          PROP TIME              J              PROP TIME RATIO       AVE ACCEL
  8.6595241412       0.6337600000      1519.2050826052      1.0241766936        1.0000000000        0.0001799814
                                        MASS COMPONENT BREAKDOWN
    INITIAL           PROPULSION          PROPELLANT          TANKAGE             STRUCTURE            PAYLOAD
  2369.6249929452    262.2536886154     429.0728049390      42.9072804939         0.0             1635.3912188969

---------- NOMINAL TRAJECTORY  3 (TOTAL  16) ---------- INHIBITOR IS   3.9063D-03 ----------
                                        INDEPENDENT PARAMETERS
 1,PRIM1( 5.3133875D 00)  2,PRIM2( 3.3268842D 00)  3,PRIM3(-2.1717072D 00)  4,PDOT1(-2.0695322D 00)  5,PDOT2( 4.7840736D 00)
 6,PDOT3( 3.1878921D-01) 11,ACCEL( 1.6099008D-04) 13,VINF1( 6.7247596D 03) 15,TIME1(-1.5190481D 03) 30,LDEGR(-3.1763748D-03)
                                        DEPENDENT PARAMETERS
 1,DELTA X(-7.411780D-04)  2,DELTA Y( 8.365560D-02)  3,DELTA Z(-1.094680D-02)  4,DELT XD(-5.153640D-02)  5,DELT YD( 4.915210D-02)
 6,DELT ZD( 8.262910D-03) 11, POWER ( 8.455770D 00) 13,T,VINF1(-2.379390D-02) 15,T,TIME1( 1.664000D-03) 30,T,DEGRD( 1.443200D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1206.867  OFF   1375.891  ON    1519.048  ON
                                      ELECTRIC PROPULSION PARAMETERS
    POWER            EFFICIENCY          PROP TIME              J              PROP TIME RATIO       AVE ACCEL
  8.4557672000       0.6337600000      1350.0244116041      0.8691215491        0.8887305043        0.0001756068
                                        MASS COMPONENT BREAKDOWN
    INITIAL           PROPULSION          PROPELLANT          TANKAGE             STRUCTURE            PAYLOAD
  2340.9387961429    256.0829096522     373.4807477299      37.3480747730         0.0             1674.0270639878
```

```
------------------------------------------------------------------------------------------------------------------------
---------- NOMINAL TRAJECTORY  4 (TOTAL  19) ---------- INHIBITOR IS   1.52590-05 ---------------------------------------
------------------------------------------------------------------------------------------------------------------------
                                                  INDEPENDENT PARAMETERS
  1.PRIM1( 5.3132020D 00)   2.PRIM2( 3.3269287D 00)   3.PRIM3(-2.1715769D 00)   4.PDOT1(-2.0689020D 00)   5.PDOT2( 4.7827008D 00)
  6.PDOT3( 3.1889725D-01)  11.ACCEL( 1.6258740D-04)  13.VINF1( 6.7131835D 03)  15.TIME1(-1.5191023D 03)  30.LDEGR(-6.1577463D-03)
                                                  DEPENDENT PARAMETERS
  1.DELTA X(-5.60128D-03)   2.DELTA Y(-1.72518D-02)   3.DELTA Z( 2.42312D-04)   4.DELT XD(-1.73773D-03)   5.DELT YD(-1.22757D-02)
  6.DELT ZD( 8.54559D-03)  11. POWER ( 8.56555D 00)  13.T.VINF1(-2.85065D-02)  15.T.TIME1( 4.81076D-04)  30.T.DEGRD(-1.46812D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1236.139  OFF    1372.865  ON    1519.102  ON
                                             ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY            PROP TIME              J               PROP TIME RATIO        AVE ACCEL
    8.5655498465         0.6337600000       1382.3770869819       0.8952147629         0.9099960737          0.0001776305
                                                  MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION            PROPELLANT            TANKAGE             STRUCTURE             PAYLOAD
  2348.0346249507      259.4076771027        380.8594236109       38.0859423611          0.0              1669.6815818760

------------------------------------------------------------------------------------------------------------------------
---------- NOMINAL TRAJECTORY  5 (TOTAL  22) ---------- INHIBITOR IS   5.9605D-08 ---------------------------------------
------------------------------------------------------------------------------------------------------------------------
                                                  INDEPENDENT PARAMETERS
  1.PRIM1( 5.2191362D 00)   2.PRIM2( 3.2734061D 00)   3.PRIM3(-2.1659385D 00)   4.PDOT1(-2.0287369D 00)   5.PDOT2( 4.6843639D 00)
  6.PDOT3( 3.0652065D-01)  11.ACCEL( 1.6373773D-04)  13.VINF1( 6.7146376D 03)  15.TIME1(-1.5190635D 03)  30.LDEGR(-7.2061816D-03)
                                                  DEPENDENT PARAMETERS
  1.DELTA X( 1.33510D-03)   2.DELTA Y( 2.14569D-03)   3.DELTA Z(-2.39479D-03)   4.DELT XD(-3.35654D-03)   5.DELT YD(-1.53897D-03)
  6.DELT ZD( 3.88323D-03)  11. POWER ( 8.62288D 00)  13.T.VINF1(-1.21597D-02)  15.T.TIME1( 4.41532D-04)  30.T.DEGRD(-2.53145D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1232.409  OFF    1374.451  ON    1519.064  ON
                                             ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY            PROP TIME              J               PROP TIME RATIO        AVE ACCEL
    8.6228773519         0.6337600000       1377.0217396572       0.9071750874         0.9064938549          0.0001789778
                                                  MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION            PROPELLANT            TANKAGE             STRUCTURE             PAYLOAD
  2347.1431552637      261.1438406008        382.7034428903       38.2703442890          0.0              1665.0255274835

------------------------------------------------------------------------------------------------------------------------
---------- NOMINAL TRAJECTORY  6 (TOTAL  27) ---------- INHIBITOR IS   7.4506D-09 ---------------------------------------
------------------------------------------------------------------------------------------------------------------------
                                                  INDEPENDENT PARAMETERS
  1.PRIM1( 5.1599153D 00)   2.PRIM2( 3.2549972D 00)   3.PRIM3(-2.1596535D 00)   4.PDOT1(-2.0104620D 00)   5.PDOT2( 4.6285800D 00)
  6.PDOT3( 2.8988390D-01)  11.ACCEL( 1.6440323D-04)  13.VINF1( 6.7141174D 03)  15.TIME1(-1.5189516D 03)  30.LDEGR(-5.9051982D-03)
                                                  DEPENDENT PARAMETERS
  1.DELTA X( 7.45271D-04)   2.DELTA Y(-6.39267D-04)   3.DELTA Z(-1.51192D-03)   4.DELT XD(-7.33083D-04)   5.DELT YD(-3.71706D-03)
  6.DELT ZD( 1.70128D-03)  11. POWER ( 8.65910D 00)  13.T.VINF1(-3.47048D-03)  15.T.TIME1(-1.05360D-05)  30.T.DEGRD(-1.24976D-03)
THRUST SWITCHING TIMES (DAYS)        0.0    ON    1237.403  OFF    1369.671  ON    1518.952  ON
                                             ELECTRIC PROPULSION PARAMETERS
     POWER              EFFICIENCY            PROP TIME              J               PROP TIME RATIO        AVE ACCEL
    8.6591006747         0.6337600000       1386.6839452631       0.9231469282         0.9129217404          0.0001799027
                                                  MASS COMPONENT BREAKDOWN
     INITIAL            PROPULSION            PROPELLANT            TANKAGE             STRUCTURE             PAYLOAD
  2347.4620903736      262.2408639344        387.0564540190       38.7066454019          0.0              1659.4481270183
```

```
--------- NOMINAL TRAJECTORY  7 (TOTAL  32) ---------- INHIBITOR IS   1.4901D-08 -----------------------------------------------
                                                  INDEPENDENT PARAMETERS
 1,PRIM1( 5.1336404D 00)   2,PRIM2( 3.2629313D 00)   3,PRIM3(-2.1557714D 00)   4,PDOT1(-2.0141728D 00)   5,PDOT2( 4.6048409D 00)
 6,PDOT3( 2.8387868D-01)  11,ACCEL( 1.6460417D-04)  13,VINF1( 6.7137432D 03)  15,TIME1(-1.5187710D 03)  30,LDEGR(-5.1412997D-03)
                                                  DEPENDENT PARAMETERS
 1,DELTA X( 2.359270-04)   2,DELTA Y(-1.07608D-04)   3,DELTA Z(-5.52100D-04)   4,DELT XD(-3.29142D-04)   5,DELT YD(-3.09067D-03)
 6,DELT ZD( 7.41430D-04)  11, POWER ( 8.67053D 00)  13,T,VINF1(-6.54911D-04)  15,T,TIME1(-2.23881D-04)  30,T,DEGRD(-4.99774D-04)
THRUST SWITCHING TIMES (DAYS)        0.0    ON     1239.035  OFF    1368.048  ON     1518.771  ON
                                              ELECTRIC PROPULSION PARAMETERS
    POWER               EFFICIENCY          PROP TIME                J               PROP TIME RATIO         AVE ACCEL
     8.6705313436        0.6337600000      1389.7585967565       0.9280672161         0.9150547169          0.0001801835
                                                  MASS COMPONENT BREAKDOWN
    INITIAL             PROPULSION          PROPELLANT            TANKAGE             STRUCTURE              PAYLOAD
  2347.6914743591      262.5870417409      388.4296679449       38.8429667945          0.0                1657.8317978787

--------- NOMINAL TRAJECTORY  8 (TOTAL  36) ---------- INHIBITOR IS   3.7253D-09 -----------------------------------------------
                                                  INDEPENDENT PARAMETERS
 1,PRIM1( 5.1088483D 00)   2,PRIM2( 3.2963260D 00)   3,PRIM3(-2.1550970D 00)   4,PDOT1(-2.0358208D 00)   5,PDOT2( 4.5872536D 00)
 6,PDOT3( 2.9845884D-01)  11,ACCEL( 1.6467645D-04)  13,VINF1( 6.7147767D 03)  15,TIME1(-1.5184032D 03)  30,LDEGR(-4.8228501D-03)
                                                  DEPENDENT PARAMETERS
 1,DELTA X( 2.39729D-04)   2,DELTA Y(-1.27285D-04)   3,DELTA Z(-8.13075D-05)   4,DELT XD(-1.09389D-04)   5,DELT YD(-1.96172D-03)
 6,DELT ZD( 4.01517D-04)  11, POWER ( 8.67200D 00)  13,T,VINF1(-1.33191D-04)  15,T,TIME1(-1.48701D-04)  30,T,DEGRD(-1.80187D-04)
THRUST SWITCHING TIMES (DAYS)        0.0    ON     1238.824  OFF    1363.853  ON     1518.403  ON
                                              ELECTRIC PROPULSION PARAMETERS
    POWER               EFFICIENCY          PROP TIME                J               PROP TIME RATIO         AVE ACCEL
     8.6719973228        0.6337600000      1393.3738931869       0.9324605011         0.9176574035          0.0001803267
                                                  MASS COMPONENT BREAKDOWN
    INITIAL             PROPULSION          PROPELLANT            TANKAGE             STRUCTURE              PAYLOAD
  2347.0578738041      262.6314389198      389.7150553728       38.9715055373          0.0                1655.7398739742

--------- NOMINAL TRAJECTORY  9 (TOTAL  39) ---------- INHIBITOR IS   1.1642D-10 -----------------------------------------------
                                                  INDEPENDENT PARAMETERS
 1,PRIM1( 5.0760147D 00)   2,PRIM2( 3.3463430D 00)   3,PRIM3(-2.1582755D 00)   4,PDOT1(-2.0671646D 00)   5,PDOT2( 4.5669170D 00)
 6,PDOT3( 3.2898985D-01)  11,ACCEL( 1.6477406D-04)  13,VINF1( 6.7174629D 03)  15,TIME1(-1.5178833D 03)  30,LDEGR(-4.6613107D-03)
                                                  DEPENDENT PARAMETERS
 1,DELTA X( 4.84058D-04)   2,DELTA Y(-9.14775D-04)   3,DELTA Z(-1.93914D-05)   4,DELT XD( 2.63154D-04)   5,DELT YD(-7.39846D-04)
 6,DELT ZD( 1.52396D-04)  11, POWER ( 8.67105D 00)  13,T,VINF1(-1.43676D-04)  15,T,TIME1( 9.64158D-06)  30,T,DEGRD(-3.70422D-06)
THRUST SWITCHING TIMES (DAYS)        0.0    ON     1237.601  OFF    1356.688  ON     1517.883  ON
                                              ELECTRIC PROPULSION PARAMETERS
    POWER               EFFICIENCY          PROP TIME                J               PROP TIME RATIO         AVE ACCEL
     8.6710499330        0.6337600000      1398.7961204684       0.9390740281         0.9215439260          0.0001805308
                                                  MASS COMPONENT BREAKDOWN
    INITIAL             PROPULSION          PROPELLANT            TANKAGE             STRUCTURE              PAYLOAD
  2345.4111595641      262.6027472223      391.5490838753       39.1549083875          0.0                1652.1044200790

THIS CASE IS CONVERGED.

    40 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND    9 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.
```

CASE 1

SWITCH POINT SUMMARY

PAGE 1

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
S	LS	DENSITY	DPOWR	DPOWD	DEGRAD	CHI	CHI REF

EARTH

START OF TRAJECTORY, THRUST ON

0.0	1.88051647D 00	4.59968606D-01	3.61057023D 00	1.19246544D 02	1.80000000D 02	1.01599843D 00	0.0
4.96384945D-01	-8.86484515D-01	0.0	1.03372294D 00	6.02045556D-01	-7.54731520D-02	1.00000000D 00	2.72282147D-02
5.07390960D 00	3.34883875D 00	-2.15881492D 00	-2.06852277D 00	4.56573081D 00	3.31035699D-01	1.00000000D 00	-1.37300066D-02
0.0	0.0	0.0	7.63106077D 01	6.67251942D 01	1.21764260D 00	9.79862918D-01	5.23836841D 00
-1.59489053D 01	9.40953232D 01	9.39374288D 01	0.0	-6.07534559D 01	-9.68272173D-01	1.19864013D 00	0.0
0.0	-4.65592672D-03	9.68754933D-01	-1.24543143D 00	6.53083836D-01	1.00000000D 00	0.0	0.0

SWITCH THRUST OFF

1.23683102D 03	2.67049672D 00	4.90630378D-01	1.08825737D 01	1.25632040D 02	6.67674540D 01	2.73670624D 00	2.52946051D 02
-2.63611211D 00	-5.61296528D-01	4.74784359D-01	3.96566435D-01	-4.46020316D-01	-1.20115403D-02	8.71352371D-01	6.03287311D-03
3.75307033D-01	-1.41086288D 00	7.03135538D-01	1.92992332D-01	1.80125840D-01	-9.05853695D-01	1.77017914D 00	-1.37301267D-02
-1.95211637D 01	-1.88467069D-01	0.0	8.09210446D 01	1.30145263D 02	1.42395914D 00	1.90743054D-01	-1.27051147D-14
2.14624934D 01	8.81060683D 01	8.82374416D 01	9.99065272D 00	-1.67979755D 02	-2.93507184D 01	5.96945006D-01	1.23683102D 03
1.97788487D 02	-2.27625848D-04	1.33519174D-01	-1.27813680D-01	1.30988114D 00	9.72606606D-01	9.00000000D 01	9.00000000D 01

SWITCH THRUST ON

1.35715295D 03	2.67049672D 00	4.90630378D-01	1.08825737D 01	1.25632040D 02	9.63835672D 01	2.06764574D 00	2.82562264D 02
-1.50614591D 00	-1.36241789D 00	3.87944452D-01	7.10632357D-01	-2.85511823D-01	-7.90536006D-02	8.71352371D-01	1.00425665D-02
7.14174926D-01	-8.62338171D-01	-1.17179606D 00	1.30527923D-01	3.72514782D-01	-8.54746384D-01	1.77017914D 00	-1.37301267D-02
-1.95211637D 01	-1.88467069D-01	0.0	7.29375879D 01	5.70636244D 01	1.42395914D 00	3.14908724D-01	-8.23993651D-17
-4.44996537D 01	9.85505580D 01	9.60875600D 01	1.08142825D 01	-1.37868379D 02	-2.65512448D 01	7.69949037D-01	1.23683102D 03
1.97788487D 02	-2.27625848D-04	2.33909434D-01	-2.64923277D-01	1.17089652D 00	9.72606808D-01	0.0	0.0

TEMPEL II(1988)

END OF TRAJECTORY, THRUST ON

1.51785637D 03	3.03673004D 00	5.44431648D-01	1.24316650D 01	1.19119131D 02	1.91041078D 02	1.38343810D 00	3.70829354D 02
8.86771280D-01	-1.06032284D 00	-5.70362666D-02	7.86262148D-01	6.69570707D-01	-2.23246432D-01	8.33184679D-01	2.02263078D-02
6.32371134D-01	9.39816712D-01	-2.18494377D 00	-4.08075153D-01	8.72622840D-01	5.18177314D-01	1.88473916D 00	-1.37301441D-02
-2.05246983D 01	-2.61343285D-01	0.0	7.95785650D 01	2.02254602D 01	1.45172306D 00	6.06462629D-01	8.16486183D-01
-5.11364286D 01	9.83736007D 01	9.52427968D 01	-2.36285515D 00	-5.00935201D 01	2.63376380D-04	1.05658510D 00	1.39753444D 03
2.59774436D 02	2.21148515D-08	5.22493074D-01	-5.79867479D-01	9.00641530D-01	9.64177329D-01	0.0	0.0

```
CASE  1                                        ITERATOR SUMMARY

                                           INDEPENDENT PARAMETERS

 1,PRIM1( 5.0739096D 00)   2,PRIM2( 3.3488387D 00)   3,PRIM3(-2.1588149D 00)   4,PDOT1(-2.0685228D 00)   5,PDOT2( 4.5657308D 00)
 6,PDOT3( 3.3103570D-01)   7,LMASS( 1.0000000D 00)   8, LTAU( 0.0          )   9,     ( 0.0          )  10,DECLN( 0.0          )
11,ACCEL( 1.6478510D-04)  12,V JET( 2.8439285D 04)  13,VINF1( 6.7177410D 03)  14,VINF2( 0.0          )  15,TIME1(-1.5178564D 03)
16,TIME2( 0.0          )  17,IPARK( 0.0          )  18,VELO1( 0.0          )  19,VELO2( 0.0          )  20,VELO3( 0.0          )
21,THET1( 0.0          )  22,THET2( 0.0          )  23,THET3( 0.0          )  24,THET4( 0.0          )  25,THET5( 0.0          )
26,THET6( 0.0          )  27,THET7( 0.0          )  28,THET8( 0.0          )  29,THET9( 0.0          )  30,LDEGR(-4.6559267D-03)
31, PHI1( 0.0          )  32, PHI2( 0.0          )  33, PHI3( 0.0          )  34, PHI4( 0.0          )  35, PHI5( 0.0          )
36, PHI6( 0.0          )  37, PHI7( 0.0          )  38, PHI8( 0.0          )  39, PHI9( 0.0          )  40,PHI10( 0.0          )
41,PR1-A( 0.0          )  42,PR2-A( 0.0          )  43,PR3-A( 0.0          )  44,PD1-A( 0.0          )  45,PD2-A( 0.0          )
46,PD3-A( 0.0          )  47,VINFA( 0.0          )  48,TIMEA( 0.0          )  49,KSAMP( 0.0          )  50,KDROP( 0.0          )
51,PR1-B( 0.0          )  52,PR2-B( 0.0          )  53,PR3-B( 0.0          )  54,PD1-B( 0.0          )  55,PD2-B( 0.0          )
56,PD3-B( 0.0          )  57,VINFB( 0.0          )  58,TIMEB( 0.0          )  59,KSAMP( 0.0          )  60,KDROP( 0.0          )
61,PR1-C( 0.0          )  62,PR2-C( 0.0          )  63,PR3-C( 0.0          )  64,PD1-C( 0.0          )  65,PD2-C( 0.0          )
66,PD3-C( 0.0          )  67,VINFC( 0.0          )  68,TIMEC( 0.0          )  69,KSAMP( 0.0          )  70,KDROP( 0.0          )

                                            DEPENDENT PARAMETERS

 1,DELTA X( 4.65245D-06)   2,DELTA Y(-8.98292D-06)   3,DELTA Z(-6.49573D-07)   4,DELT XD( 2.39851D-06)   5,DELT YD(-6.47139D-06)
 6,DELT ZD( 1.01292D-06)   7,       ( 0.0        )   8,       ( 0.0        )   9,       ( 0.0        )  10,       ( 0.0        )
11, POWER ( 8.67100D 00)  12,       ( 0.0        )  13,T,VINF1(-1.06427D-06)  14,       ( 0.0        )  15,T,TIME1( 7.73449D-08)
16,       ( 0.0        )  17,       ( 0.0        )  18,       ( 0.0        )  19,       ( 0.0        )  20,       ( 0.0        )
21,       ( 0.0        )  22,       ( 0.0        )  23,       ( 0.0        )  24,       ( 0.0        )  25,       ( 0.0        )
26,       ( 0.0        )  27,       ( 0.0        )  28,       ( 0.0        )  29,       ( 0.0        )  30,T,DEGRD( 2.21149D-08)
31,       ( 0.0        )  32,       ( 0.0        )  33,       ( 0.0        )  34,       ( 0.0        )  35,       ( 0.0        )
36,       ( 0.0        )  37,       ( 0.0        )  38,       ( 0.0        )  39,       ( 0.0        )  40,       ( 0.0        )
41,       ( 0.0        )  42,       ( 0.0        )  43,       ( 0.0        )  44,       ( 0.0        )  45,       ( 0.0        )
46,       ( 0.0        )  47,       ( 0.0        )  48,       ( 0.0        )  49,       ( 0.0        )  50,       ( 0.0        )
51,       ( 0.0        )  52,       ( 0.0        )  53,       ( 0.0        )  54,       ( 0.0        )  55,       ( 0.0        )
56,       ( 0.0        )  57,       ( 0.0        )  58,       ( 0.0        )  59,       ( 0.0        )  60,       ( 0.0        )
61,       ( 0.0        )  62,       ( 0.0        )  63,       ( 0.0        )  64,       ( 0.0        )  65,       ( 0.0        )
66,       ( 0.0        )  67,       ( 0.0        )  68,       ( 0.0        )  69,       ( 0.0        )  70,       ( 0.0        )

THRUST SWITCHING TIMES (DAYS)        0.0    ON     1236.831  OFF    1357.153  ON     1517.856  ON

                                     ELECTRIC PROPULSION PARAMETERS
     POWER            EFFICIENCY        PROP TIME              J              PROP TIME RATIO      AVE ACCEL
  8.6710000072       0.6337600000   1397.5344446940      0.9382774144        0.9207290424       0.0001805291

                                       MASS COMPONENT BREAKDOWN
    INITIAL           PROPULSION        PROPELLANT          TANKAGE           STRUCTURE           PAYLOAD
 2345.2405989059    262.6012352180    391.2220623059     39.1222062306        0.0             1652.2950951515


SWITCH-COUNT HISTORY    2.2.4.4.4.4.4.4.4/

  204 THRUST COMPUTE STEPS.      7 COAST COMPUTE STEPS
```

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION		THRUST ANGLES PSI		THRUST ANGLES THETA		THRUST ANGLES PHI		INPUT POWER		ARRAY ANGLE
0	0.0	0.0		1.016		86.1		0.0	ON	5.24D 00		-15.9		94.1		93.9		8.5	ON	0.0
4	1.834	2.1		1.016		87.7		0.01		5.25D 00		-15.8		93.4		93.3	MAX	8.5		0.0
4	2.644	3.1	MIN	1.016		88.4		0.01		5.25D 00		-15.7		93.1		93.0		8.5		0.0
4	13.958	16.2		1.024		98.7		0.05	MAX	5.30D 00		-14.4		88.8		88.9		8.4		0.0
5	83.425	80.3		1.364	MAX	166.0		0.38		4.45D 00		-0.4		69.7		69.7		5.5		0.0
4	152.250	114.2		1.867		115.4		1.22		3.83D 00		19.1		62.8	MIN	64.5		3.3		0.0
5	173.169	121.2		2.016		101.0		1.58	MIN	3.30D 00		24.6		62.0		64.8		2.9		0.0
4	226.549	135.4		2.372		67.2		2.57		3.94D 00		36.5	MIN	61.3		67.3		2.2		0.0
5	339.725	155.6		2.992	MIN	0.9		4.01		4.55D 00		51.5		63.0		73.6		1.4		0.0
7	367.048	159.4		3.115		16.9	MAX	4.07		4.70D 00		53.6		63.7		74.8		1.3		0.0
7	539.712	178.8		3.679		171.8	MIN	2.70		5.18D 00		61.0		68.7		79.9		1.0		0.0
5	546.123	179.4		3.694	MAX	178.3		2.71		5.19D 00		61.1		66.9		80.0		0.9		0.0
4	555.805	180.3		3.714		167.8		2.75	MAX	5.13D 00		61.3		69.2		80.2		0.9		0.0
4	714.156	194.5		3.913		24.1		4.82		4.85D 00	MAX	62.7		73.5		82.5		0.8		0.0
5	748.378	197.5		3.922		2.8	MAX	4.93		4.59D 00		62.7		74.3		82.9		0.8		0.0
5	748.744	197.5		3.922	MIN	2.8		4.93		4.59D 00		62.7		74.3		82.9		0.8		0.0
4	757.403	198.3	MAX	3.922		6.6		4.93		4.55D 00		62.6		74.5		83.0		0.8		0.0
5	759.248	198.4		3.922		7.8		4.92		4.54D 00		62.6		74.6		83.0	MIN	0.8		0.0
5	946.761	215.3		3.742	MAX	172.0		2.76		3.23D 00		59.7		78.9		84.4		0.9		0.0
5	953.421	216.0		3.729		168.6	MIN	2.75		3.17D 00		59.5		79.0		84.5		0.9		0.0
4	1131.643	236.1		3.207		17.6	MAX	4.16		1.13D 00		47.6		83.6		85.7		1.2		0.0
4	1157.452	239.7		3.103	MIN	6.7		4.10		8.55D-01		43.7		84.5		86.1		1.3		0.0
4	1236.831	252.8		2.737		50.4		3.25	OFF	-1.27D-14		21.5		88.1		88.2		1.7		0.0
5	1296.317	265.5		2.420		89.3		2.22	MIN	-2.87D-01		*****		******		*****		0.0		90.0
7	1357.153	282.9		2.068		134.8		1.24	ON	-8.24D-17		-44.5		98.6		96.1		2.7		0.0
5	1394.950	297.1		1.845	MAX	158.0		0.87		3.37D-01		-54.7		102.7		97.3		3.3		0.0
6	1432.834	315.0		1.636		133.2	MIN	0.76		6.55D-01		-58.8		105.2		97.8		4.0		0.0
5	1441.845	319.9		1.591		125.7		0.77		7.17D-01		-59.1		105.4	MAX	97.8		4.2		0.0
4	1444.313	321.3		1.579		123.8		0.77		7.33D-01		-59.1	MAX	105.4		97.8		4.3		0.0
4	1446.468	322.6		1.569		122.1		0.77		7.45D-01	MIN	-59.1		105.4		97.8		4.3		0.0
4	1489.227	350.0		1.417		97.8		0.86	MAX	8.79D-01		-56.3		102.6		96.9		5.1		0.0
4	1517.072	370.1		1.383		89.4		0.96		8.20D-01		-51.3		98.5		95.3	MAX	5.3		0.0
3	1517.855	370.7	MIN	1.383		89.2		0.96		8.15D-01		-51.1		98.4		95.2		5.3		0.0
4	1517.856	370.7		1.383		89.2		0.96	ON	8.15D-01		-51.1		98.4		95.2		5.3	ON	0.0

MISSION SCHEDULE

JULY 21, 1984 2.0667050 3D 01 G.M.T.
2445903.361D 00 JULIAN DATE

DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	4.9638494D-01	-8.8648451D-01	0.0	8.5633575D-01	4.8496863D-01	0.0	1.0159984D 00	0.0	-60.753
S/C	4.9638494D-01	-8.8648451D-01	0.0	1.0337229D 00	6.0204556D-01	-7.5473152D-02	1.0159984D 00	0.0	-60.753

SEPTEMBR 16, 1988 1.7220000 0D 01 G.M.T.
2447421.218D 00 JULIAN DATE

ARRIVE AT TEMPEL II(1988)

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	8.8676663D-01	-1.0603139D 00	-5.7035617D-02	7.8625975D-01	6.6957718D-01	-2.2324744D-01	1.3834282D 00	-2.363	-50.093
S/C	8.8677128D-01	-1.0603229D 00	-5.7036267D-02	7.8525215D-01	6.6957071D-01	-2.2324643D-01	1.3834381D 00	-2.363	-50.094

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND TEMPEL II(1988) IS 10.9158 DEGREES.

CASE 1 (CONVERGED) PERFORMANCE SUMMARY

EARTH TO TEMPEL II(1988) WITH FIXED ARRIVAL EXCESS SPEED

ARRIVAL AT TEMPEL II(1988) PERIHELION

LAUNCH VEHICLE IS TITAN III E/CENTAUR (COEFFICIENTS = 167238.9500 3480.2038 1753.6965)

LD = JUL 21, 1984, 20.6671 HOURS GMT AD = SEP 16, 1988, 17.2200 HOURS GMT FLIGHT TIME = 1517.8564 DAYS.
JULIAN DATE 45903.3611 JULIAN DATE 47421.2175

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
15.0000	15.2850	0.1000	0.0	0.63376	0.0	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
2345.2406	262.6012	391.2221	39.1222	0.0	1652.2951

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
8.6710	0.0	5.2586	0.386461	1.647851D-04	2900.000	0.63376	7.1210000D 03 CONSTRAINED MAX

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
3.9221510	1.0155371	8.498784	0.37878516	1397.53444	259.77444	370.82935

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-5.7634	28.5000	6717.74104	45.128045	0.20776	0.000000

H. MULTIPLE BALLISTIC SWINGBY MISSION

This computer run demonstrates how the program may be effectively used in the investigation of all-ballistic missions (with electric propulsion absent).

In general, trajectories are forced to be all-ballistic by setting the propulsion-time adjoint variable X8 to a "large" negative number (X8 = - 1.D3) with respect to the mass ratio adjoint variable X7 = 1.D0. These settings (together with the reference thrust acceleration X11 = 1.D-4, jet exhaust speed X12 = 1.D0, and non-zero primer vector components X2 = .1D0 at the launch planet and X42 = .1D0 at the first intermediate-target) guarantee that the electric propulsion thrust switch-function will be maintained negative, yielding ballistic flight at all times. The electric propulsion specific masses ALPHAA and ALPHAT are also set to zero, so that the net spacecraft mass equals the launch vehicle payload.

The particular ballistic mission simulation demonstrated here involves a March 6, 1985 launch of a 1,635 kg payload by an Atlas/Centaur launch vehicle (using the launch vehicle selection default-value of MBOOST = 0; actually, changing MBOOST alters the payload mass computation but not the C_3 or the trajectory).

The primary target is the Earth, specified by MOPT3 = 3, and there is one intermediate target, the comet Giacobini-Zinner, specified by MOPTX = 41. The launch occurs fifteen days before (X15 = - 15.D0) the reference date (MYEAR = 1985, MONTH = 3, MDAY = 21), and the spacecraft passes Giacobini-Zinner 174.22 days (X48) after the reference date and arrives back at Earth 353 days (X16) after the reference date.

Ten days after passing Giacobini-Zinner a deep-space burn (of 188.9 m/sec) makes possible the re-targeting to Earth. This is accomplished by inputting TDV = 1.00010D5 together with X64(2), X65(2), and X66(2) = 1.D0.

The deep space burn velocity-increment (X64, X65, X66) initial guess is the zero vector, by default. The deep-space burn could just have well occurred before arriving at Giacobini-Zinner (e.g., TDV = 2.000005D5). The iteration sequence consists of a 6x6 hunt, with the independent variables being the initial heliocentric velocity at Earth (X18, X19, X20) and the deep-space burn velocity increment (X64, X65, X66), and the dependent variables being the position targeting at Giacobini-Zinner (Y41, Y42, Y43) and at Earth (Y1, Y2, Y3). The setting MAXHAM = 0 is made to avoid unwarranted BAD HAMILTONIAN warning messages due to the presence of the deep-space burn.

The detailed printout of the iteration sequence is omitted by setting NPRINT = 3 (compared to the default value NPRINT = 7), and three extra lines are added to each print-block by setting MPRINT = 2.

Finally, the multiple ballistic swingby option is invoked by means of MOPT4 = - 3, 42, which directs the spacecraft to swingby the primary target (Earth) in such a manner as to re-target to Earth (MOPT4(1) = - 3), and then, at the second Earth passage, to again swingby in such a manner as to target to the comet Borrelly (MOPT4(2) = 42). Furthermore, the first Earth swingby is specified as unpowered (MSWING(1) = - 1) having T2(1) = 480 days as the initial guess of the Earth-to-Earth transfer time, and the second Earth swingby is specified to be powered (MSWING(2) = - 5) with a specified transfer time from Earth to Borrelly (T2(2) = 127 days) and using the input Earth-departure heliocentric velocity initial-guess XSWING(1, 2) = .62D0, .91D0, 0.D0. Both swingby iterations converged, and the powered-swingby incremental speed turned out to be -13.7 m/sec, the minus sign denoting a braking burn. The default value of TGO = - 1.D0 resulted in the printout of several pages describing the trajectory segments following the time of primary target passage.

It should be noted that the trajectory simulation would have terminated at the primary target (first Earth encounter) if MOPT4(1) were zero, and would have terminated at the second Earth encounter had MOPT4(2) been zero. The

mission, as simulated, thus consists initially of a comet-flyby, followed by a second comet-flyby making use of a double Earth-swingby to reach the second comet.

The inputs for this computer run are listed below, and the resulting program output is displayed on the following pages.

```
&MINPUT X7=1.D0,X2=.1D0,X42=.1D0,X8=-1.D3,ALPHAA=0.D0,ALPHAT=0.D0
X64(2)=1.D0,X65(2)=1.D0,X66(2)=1.D0,X18(2)=1.D0,X19(2)=1.D0,X20(2)=1.D0
Y1(2)=1.D0,Y2(2)=1.D0,Y3(2)=1.D0,Y41(2)=1.D0,Y42(2)=1.D0,Y43(2)=1.D0
MYEAR=1985,MONTH=3,MDAY=21,MOPT2=3,MOPT3=3,MOPTX=41,X11=1.D-4,X12=1.D0
TDV=1.00010D5,X15=-15.D0,X16=353.D0,X48=174.22D0
X18=-8.3276D-2,X19=-1.0034D0,X20=-2.0143D-3
T2=480.D0,127.D0,XSWING(1,2)=.62D0,.91D0,0.D0
MOPT4=-3,42,MSWING=-1,-5,MPRINT=2,MAXHAM=0,NPRINT=3 &END
```

CASE 1 TIME TO GO CPU 59, I/O 43 SEC

PROGRAM INPUTS

X 1 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 2 =	1.0000000000000000D-01,	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 3 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 4 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 5 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 6 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X 7 =	1.0000000000000000D 00,	0.0	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 8 =	-1.0000000000000000D 03,	0.0	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X 9 =	0.0	0.0	3.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X10 =	0.0	0.0	9.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X11 =	9.9999999999999999D-05,	0.0	9.9999999999999999D-04,	1.0000000000000000D-11,	1.0000000000000000D 00,
X12 =	1.0000000000000000D 00,	0.0	2.0000000000000000D 03,	9.9999999999999999D-04,	1.0000000000000000D 00,
X13 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X14 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999999D-04,	1.0000000000000000D 00,
X15 =	-1.5000000000000000D 01,	0.0	8.0000000000000000D 00,	9.9999999999999999D-07,	1.0000000000000000D 00,
X16 =	3.5300000000000000D 02,	0.0	1.0000000000000000D 02,	9.9999999999999999D-07,	1.0000000000000000D 00,
X17 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X18 =	-8.3276000000000000D-02,	1.0000000000000000D 00,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X19 =	-1.6034000000000000D 00,	1.0000000000000000D 00,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X20 =	-2.0143000000000000D-03,	1.0000000000000000D 00,	1.0000000000000000D 00,	9.9999999999999999D-05,	1.0000000000000000D 00,
X21 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X22 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X23 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X24 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X25 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X26 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X27 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X28 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X29 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X30 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X31 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X32 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X33 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X34 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X35 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X36 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X37 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X38 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X39 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X40 =	0.0	0.0	1.0000000000000000D 01,	9.9999999999999999D-05,	1.0000000000000000D 00,
X41 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X42 =	1.0000000000000000D-01,	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X43 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X44 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X45 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X46 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X47 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X48 =	1.7422000000000000D 02,	0.0	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X49 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X50 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X51 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X52 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X53 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X54 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X55 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X56 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X57 =	0.0	0.0	5.0000000000000000D 02,	9.9999999999999999D-05,	1.0000000000000000D 00,
X58 =	0.0	0.0	5.0000000000000000D 01,	9.9999999999999999D-07,	1.0000000000000000D 00,
X59 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,
X60 =	0.0	0.0	3.0000000000000000D 00,	1.0000000000000000D-08,	1.0000000000000000D 00,

X61 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X62 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X63 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X64 =	0.0	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X65 =	0.0	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X66 =	0.0	1.000000000000000D 00,	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X67 =	0.0	0.0	5.000000000000000D 02,	9.999999999999999D-05,	1.000000000000000D 00,
X68 =	0.0	0.0	5.000000000000000D 01,	9.999999999999999D-07,	1.000000000000000D 00,
X69 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
X70 =	0.0	0.0	3.000000000000000D 00,	1.000000000000000D-08,	1.000000000000000D 00,
Y 1 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y 2 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y 3 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y 4 =	0.0	0.0	9.999999999999999D-05,		
Y 5 =	0.0	0.0	9.999999999999999D-05,		
Y 6 =	0.0	0.0	9.999999999999999D-05,		
Y 7 =	0.0	0.0	9.999999999999999D-05,		
Y 8 =	0.0	0.0	9.999999999999999D-05,		
Y 9 =	0.0	0.0	9.999999999999999D-05,		
Y10 =	0.0	0.0	9.999999999999999D-05,		
Y11 =	0.0	0.0	9.999999999999999D-05,		
Y12 =	0.0	0.0	9.999999999999999D-05,		
Y13 =	0.0	0.0	9.999999999999999D-05,		
Y14 =	0.0	0.0	9.999999999999999D-05,		
Y15 =	0.0	0.0	9.999999999999999D-05,		
Y16 =	0.0	0.0	9.999999999999999D-05,		
Y17 =	0.0	0.0	9.999999999999999D-05,		
Y18 =	0.0	0.0	9.999999999999999D-05,		
Y19 =	0.0	0.0	9.999999999999999D-05,		
Y20 =	0.0	0.0	9.999999999999999D-05,		
Y21 =	0.0	0.0	9.999999999999999D-05,		
Y22 =	0.0	0.0	9.999999999999999D-05,		
Y23 =	0.0	0.0	9.999999999999999D-05,		
Y24 =	0.0	0.0	9.999999999999999D-05,		
Y25 =	0.0	0.0	9.999999999999999D-05,		
Y26 =	0.0	0.0	9.999999999999999D-05,		
Y27 =	0.0	0.0	9.999999999999999D-05,		
Y28 =	0.0	0.0	9.999999999999999D-05,		
Y29 =	0.0	0.0	9.999999999999999D-05,		
Y30 =	0.0	0.0	9.999999999999999D-05,		
Y31 =	0.0	0.0	9.999999999999999D-05,		
Y32 =	0.0	0.0	9.999999999999999D-05,		
Y33 =	0.0	0.0	9.999999999999999D-05,		
Y34 =	0.0	0.0	9.999999999999999D-05,		
Y35 =	0.0	0.0	9.999999999999999D-05,		
Y36 =	0.0	0.0	9.999999999999999D-05,		
Y37 =	0.0	0.0	9.999999999999999D-05,		
Y38 =	0.0	0.0	9.999999999999999D-05,		
Y39 =	0.0	0.0	9.999999999999999D-05,		
Y40 =	0.0	0.0	9.999999999999999D-05,		
Y41 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y42 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y43 =	0.0	1.000000000000000D 00,	9.999999999999999D-05,		
Y44 =	0.0	0.0	9.999999999999999D-05,		
Y45 =	0.0	0.0	9.999999999999999D-05,		
Y46 =	0.0	0.0	9.999999999999999D-05,		
Y47 =	0.0	0.0	9.999999999999999D-05,		
Y48 =	0.0	0.0	9.999999999999999D-05,		
Y49 =	0.0	0.0	9.999999999999999D-05,		
Y50 =	0.0	0.0	9.999999999999999D-05,		
Y51 =	0.0	0.0	9.999999999999999D-05,		
Y52 =	0.0	0.0	9.999999999999999D-05,		
Y53 =	0.0	0.0	9.999999999999999D-05,		
Y54 =	0.0	0.0	9.999999999999999D-05,		
Y55 =	0.0	0.0	9.999999999999999D-05,		
Y56 =	0.0	0.0	9.999999999999999D-05,		

ORIGINAL PAGE IS
OF POOR QUALITY

```
Y57 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y58 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y59 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y60 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y61 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y62 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y63 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y64 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y65 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y66 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y67 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y68 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y69 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
Y70 =  0.0                  ,   0.0                    ,   9.999999999999999D-05,
&OUTPUT
AAI= 0.0             ,AE= 0.0              ,ALPHAA= 0.0              ,ALPHAT= 0.0              ,ALTITU=
 0.0            ,AN=  1.500000000000000  ,AR=  1.000000000000000  ,ASOL= 0.0              , 0.0             ,
 0.0            , 0.0                , 0.0                ,BI= 0.7600000000000000   ,B1= 0.0             ,B2=
 0.0            ,B3= 0.0             ,CNI= 0.0                ,CNIX=  31.87374000000000   , 0.0            ,
 0.0            , 0.0                , 0.0                ,CSTR= 0.0                ,CTANK= 0.2999999999999999D-01,
CTRET= 0.1111111111111111  ,DI=  13.00000000000000  ,DMRETR= 0.0           ,DPOW= 0.0                ,ECI=
 0.0            ,ECIX= 0.7075535000000000  , 0.0             , 0.0                , 0.0               ,
 0.0            ,EI= 0.0             ,EMUODD= 0.0             ,EMJODX= 0.0              ,
 0.0            , 0.0                , 0.0                , 0.0                ,GAMMAX=  1.000000000000000   ,GAP=
 0.9999999999999999D-04,HOUR=  12.00000000000000   ,OMI= 0.0             ,OMIX=  195.2073800000000   ,
 0.0            , 0.0                , 0.0                , 0.0                ,POWFIX= -1.000000000000000   ,
PSIGN=  1.000000000000000   ,RADODD=  1.000000000000000   ,RADODX=  1.000000000000000   , 0.0            ,
 0.0            , 0.0                , 0.0                ,RAP=  38.00000000000000   ,REVS= 0.0            ,
RPER=  2.000000000000000   ,SAI=  1.000000000000000   ,SAIX=  3.516014000000000   , 0.0            ,
 0.0            , 0.0                , 0.0                ,SOI= 0.0               ,SOIX=  172.4822300000000   ,
 0.0            , 0.0                , 0.0                , 0.0                ,SPIRET=  300.0000000000000   ,
STATE=  1.000000000000000    , 0.0            , 0.0             , 0.0            ,  1.000000000000000   ,
 0.0            ,STEP1= 0.3125000000000000D-01,STEP2= 0.1250000000000000    ,TCOAST= 0.0          ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                ,TDV=  100010.0000000000    ,TGO=
 -1.000000000000000   ,THRET=  400.0000000000000   ,TOFF= -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   , -1.000000000000000   ,
 -1.000000000000000   , -1.000000000000000   ,TPI= 0.0             ,TPIX=  168.1958333333332   , 0.0            ,
 0.0            , 0.0                , 0.0                ,TPOWER= 0.1000000000000000D 31,TSCALE=
 1.000000000000000   ,T2=  480.0000000000000   ,  127.0000000000000   ,  150.0000000000000   ,  200.0000000000000   ,
 250.0000000000000   ,  300.0000000000000   ,  350.0000000000000   ,  400.0000000000000   ,  450.0000000000000   ,
 500.0000000000000   ,XANG1= 0.0          ,XANG2= 0.0            ,XSWING= 0.0          ,
 0.0            , 0.0                , 0.6200000000000000   , 0.9100000000000000   , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                , 0.0               ,
 0.0            , 0.0                , 0.0                , 0.0                ,XO=  1.000000000000000   ,
 0.0            , 0.0                , 0.0                ,  1.000001500000000   , 0.0               ,
 0.0            ,IBAL=          0,INTPR=          0,IOUT=          0,IRK=          1,IRL=          1,IROT=          0,ISPIN=
        0,ITF=          3,ITPRNT=          0,JPP=          0,JPRINT=          0,JT=          0,KPART=          0,LAUNCH=
        0,LOADX=          0,MAXHAM=          0,MBOOST=          0,MDAY=         21,MODE=          4,MONTH=          3,MOPT=
        0,MOPTX=         41,          0,          0,          0,          0,MOPT2=          3,MOPT3=          3,MOPT4=         -3,
       42,          0,          0,          0,          0,          0,          0,          0,          0,MPOW=          0,
MPRINT=          2,MPUNCH=          0,MREAD=          0,MSWING=         -1,         -5,          0,          0,          0,
        0,          0,          0,          0,MTMASS=          0,MUPDAT=          1,MYEAR=       1985,NDIST=
        3,NHUNG=         25,NORMAL=          0,NPERF=          0,NPRINT=          3,NSET=          0,          0,        300,
        0,        300,NSWING=          0,NSWPAR=          1,NTAPE=         17
&END
```

CASE 1

ITERATOR PARAMETERS

INDEPENDENT VARIABLES

NO.	INDEX	VALUE	STEP LIMIT	PERTURBATION	WEIGHT
1	18	-8.3276000000000000D-02	1.0000000000000000D 00	9.9999999999999990D-05	1.0000000000000000D 00
2	19	-1.0034000000000000D 00	1.0000000000000000D 00	9.9999999999999990D-05	1.0000000000000000D 00
3	20	-2.0143000000000000D-03	1.0000000000000000D 00	9.9999999999999990D-05	1.0000000000000000D 00
4	64	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
5	65	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00
6	66	0.0	3.0000000000000000D 00	1.0000000000000000D-08	1.0000000000000000D 00

DEPENDENT VARIABLES

NO.	INDEX	VALUE	TOLERANCE
1	1	0.0	9.9999999999999990D-05
2	2	0.0	9.9999999999999990D-05
3	3	0.0	9.9999999999999990D-05
4	41	0.0	9.9999999999999990D-05
5	42	0.0	9.9999999999999990D-05
6	43	0.0	9.9999999999999990D-05

THIS CASE IS CONVERGED.

8 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND 3 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

CASE 1

SWITCH POINT SUMMARY

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
R1 REL	R2 REL	R3 REL	V1 REL	V2 REL	V3 REL	RMAG REL	VMAG REL
S/C NUC MAG	S/C TOT MAG	GEO NUC MAG	GEO TOT MAG	ANG(V,R)	ANG(V,XY)		
R1 REL ECL	R2 REL ECL	R3 REL ECL	V1 REL ECL	V2 REL ECL	V3 REL ECL	RMAG ECL	VMAG ECL

EARTH

START OF TRAJECTORY, THRUST OFF

0.0	9.96643137D-01	9.87735807D-02	1.01229530D-01	3.45870942D 02	1.80000000D 02	9.92238982D-01	0.0
-9.62222104D-01	2.42212345D-01	0.0	-1.48125469D-01	-9.95153753D-01	-1.76892321D-03	1.00000000D 00	1.70303186D-02
0.0	1.00000000D-01	0.0	0.0	0.0	0.0	1.00000000D 00	-2.47940469D-02
0.0	0.0	0.0	9.67331739D 01	2.82491762D 02	9.93438306D-01	1.00991974D 00	-8.65036241D 04
-9.81671658D-02	-7.58709206D 01	7.58709418D 01	0.0	1.65870942D 02	-5.66291334D 00	1.00611892D 00	0.0
-3.49582889D 08	-1.42900098D 08	3.84025044D 07	4.08434743D 01	-1.50175577D 01	-1.45372304D 01	3.79609518D 08	4.58807963D 01
1.91253369D 01	1.89370829D 01	1.91253369D 01	1.89370829D 01	2.71005439D 01	-1.84724012D 01		
-3.79705824D 07	3.39819832D 08	-1.64876024D 08	-2.41704518D 01	-3.89301082D 01	2.29856657D 00	3.79609518D 08	4.58807963D 01

GIACOB-ZIN(1985)

END OF TRAJECTORY SEGMENT 1, THRUST OFF

1.89220000D 02	9.96643137D-01	9.87735807D-02	1.01229530D-01	3.45870942D 02	2.92569026D 01	1.03183011D 00	2.09256903D 02
9.96072788D-01	2.69279731D-01	8.90960221D-04	-1.65104405D-01	9.52719015D-01	1.55112643D-03	1.00000000D 00	1.61945216D-02
8.90534139D-02	5.19545571D-02	2.91500507D-04	7.03097557D-02	-5.99105494D-02	-1.24999359D-04	1.00000000D 00	-2.47940469D-02
0.0	0.0	0.0	9.01062897D 01	7.62730611D 01	9.93438306D-01	9.60355902D-01	-9.15340905D 04
9.11813763D-02	1.51319843D 01	1.51322526D 01	4.94735194D-02	1.51278063D 01	5.29627289D 00	9.66920588D-01	0.0
-1.63493260D 01	-2.38745810D 01	-1.40731107D 01	5.03322532D-01	-1.39200454D 01	1.51302097D 01	3.21768321D 01	2.06051069D 01
-1.69850237D 01	-1.82688858D 01	1.51106013D 01	1.33954431D 01	8.83221259D 01	4.74520177D 01		
-8.55279570D 00	-3.10126809D 01	6.41739067D-01	1.55860006D 00	-3.52045428D 00	2.02422231D 01	3.21768321D 01	2.06051069D 01

GIACOB-ZIN(1985)

START OF TRAJECTORY SEGMENT 2, THRUST OFF

1.89220000D 02	9.96643137D-01	9.87735807D-02	1.01229530D-01	3.45870942D 02	2.92569026D 01	1.03183011D 00	2.09256903D 02
9.96072788D-01	2.69279731D-01	8.90960221D-04	-1.65104405D-01	9.52719015D-01	1.56112643D-03	1.00000000D 00	1.61945216D-02
8.90534139D-02	5.19545571D-02	2.91500507D-04	7.03097557D-02	-5.99105494D-02	-1.24999359D-04	1.00000000D 00	-2.47940469D-02
0.0	0.0	0.0	9.01062897D 01	7.62730511D 01	9.93438306D-01	9.60355902D-01	-9.15340905D 04
9.11813763D-02	1.51319843D 01	1.51322526D 01	4.94735194D-02	1.51278063D 01	5.29627289D 00	9.66920588D-01	0.0
-1.20874445D 07	6.81851853D 07	1.33266758D 05	-9.82665934D 00	-2.68677323D 00	4.64980206D-02	6.92484193D 07	1.01874501D 01
1.57399077D 01	1.33414852D 01	-1.00000000D 30	-1.00000000D 30	1.54705936D 02	2.61512895D-01		
1.24923929D 06	6.92370220D 07	1.33286758D 05	-1.01599126D 01	-7.47097032D-01	4.64980206D-02	6.92484193D 07	1.01874501D 01

DEEP SPACE BURN 188.9 METERS/SECOND AT 199.22 DAYS

EARTH

END OF TRAJECTORY, THRUST OFF

3.68000000D 02	9.98616572D-01	1.03484708D-01	1.07925514D-01	3.48629200D 02	1.79998265D 02	9.92956978D-01	3.62756518D 02
-9.73461071D-01	1.95798630D-01	5.66445051D-08	-9.54343053D-02	-1.00184298D 00	-1.88553052D-03	1.00000000D 00	1.70147744D-02
4.42397226D-02	5.72647197D-01	9.08642764D-04	-4.71642417D-01	9.01774272D-02	-1.06553100D-05	1.00000000D 00	-2.52050791D-02
0.0	0.0	0.0	9.61297040D 01	2.82703697D 02	9.93942806D-01	1.00899794D 00	-8.85567936D 04
-1.64883689D-02	-8.30450704D 01	8.30450707D 01	3.26851127D-06	1.68627465D 02	-5.93102027D 00	1.00637995D 00	0.0
9.37043785D 02	-4.49482319D 03	8.47396132D 00	-3.55105422D 00	-1.77653929D-01	-5.61603693D-02	4.59146582D 03	3.55593883D 00
-4.52697209D 00	-7.58024821D 00	-1.00000000D 30	-1.00000000D 30	1.76996516D 02	-9.04932867D-01		
-3.24620058D 01	4.59134325D 03	8.47396132D 00	3.51637918D 00	-5.25950998D-01	-5.61603693D-02	4.59146582D 03	3.55593883D 00

CASE 1

ITERATOR SUMMARY

INDEPENDENT PARAMETERS

```
 1.PRIM1( 0.0            )  2.PRIM2( 1.0000000D-01)  3.PRIM3( 0.0            )  4.PDOT1( 0.0            )  5.PDOT2( 0.0            )
 6.PDOT3( 0.0            )  7.LMASS( 1.0000000D 00)  8. LTAJ(-1.0000000D 03)  9.      ( 0.0            ) 10.DECLN( 0.0            )
11.ACCEL( 1.0000000D-04) 12.V JET( 1.0000000D 00) 13.VINF1( 0.0            ) 14.VINF2( 0.0            ) 15.TIME1(-1.5000000D 01)
16.TIME2( 3.5300000D 02) 17.IPARK( 0.0            ) 18.VEL01(-1.4812547D-01) 19.VEL02(-9.9515375D-01) 20.VEL03(-1.7689232D-03)
21.THET1( 0.0            ) 22.THET2( 0.0            ) 23.THET3( 0.0            ) 24.THET4( 0.0            ) 25.THET5( 0.0            )
26.THET6( 0.0            ) 27.THET7( 0.0            ) 28.THET8( 0.0            ) 29.THET9( 0.0            ) 30.LDEGR( 0.0            )
31. PHI1( 0.0            ) 32. PHI2( 0.0            ) 33. PHI3( 0.0            ) 34. PHI4( 0.0            ) 35. PHI5( 0.0            )
36. PHI6( 0.0            ) 37. PHI7( 0.0            ) 38. PHI8( 0.0            ) 39. PHI9( 0.0            ) 40.PHI10( 0.0            )
41.PR1-A( 8.9053414D-02) 42.PR2-A( 5.1954557D-02) 43.PR3-A( 2.9150051D-04) 44.PD1-A( 7.0309756D-02) 45.PD2-A(-5.9910549D-02)
46.PD3-A(-1.2499936D-04) 47.VINFA( 0.0            ) 48.TIMEA( 1.7422000D 02) 49.KSAMP( 0.0            ) 50.KDROP( 0.0            )
51.PR1-B( 0.0            ) 52.PR2-B( 0.0            ) 53.PR3-B( 0.0            ) 54.PD1-B( 0.0            ) 55.PD2-B( 0.0            )
56.PD3-B( 0.0            ) 57.VINFB( 0.0            ) 58.TIMEB( 0.0            ) 59.KSAMP( 0.0            ) 60.KDROP( 0.0            )
61.PR1-C( 0.0            ) 62.PR2-C( 0.0            ) 63.PR3-C( 0.0            ) 64.PD1-C( 5.5704329D-03) 65.PD2-C( 3.0309412D-03)
66.PD3-C( 1.4643332D-04) 67.VINFC( 0.0            ) 68.TIMEC( 0.0            ) 69.KSAMP( 0.0            ) 70.KDROP( 0.0            )
```

DEPENDENT PARAMETERS

```
 1.DELTA X(-2.169930-07)  2.DELTA Y( 3.06910D-05)  3.DELTA Z( 5.66445D-08)  4.       ( 0.0          )  5.       ( 0.0          )
 6.       ( 0.0         )  7.       ( 0.0         )  8.       ( 0.0         )  9.       ( 0.0          ) 10.       ( 0.0          )
11.       ( 0.0         ) 12.       ( 0.0         ) 13.       ( 0.0         ) 14.       ( 0.0          ) 15.       ( 0.0          )
16.       ( 0.0         ) 17.       ( 0.0         ) 18.       ( 0.0         ) 19.       ( 0.0          ) 20.       ( 0.0          )
21.       ( 0.0         ) 22.       ( 0.0         ) 23.       ( 0.0         ) 24.       ( 0.0          ) 25.       ( 0.0          )
26.       ( 0.0         ) 27.       ( 0.0         ) 28.       ( 0.0         ) 29.       ( 0.0          ) 30.       ( 0.0          )
31.       ( 0.0         ) 32.       ( 0.0         ) 33.       ( 0.0         ) 34.       ( 0.0          ) 35.       ( 0.0          )
36.       ( 0.0         ) 37.       ( 0.0         ) 38.       ( 0.0         ) 39.       ( 0.0          ) 40.       ( 0.0          )
41.DEL X A(-5.71715D-08) 42.DEL Y A(-2.07305D-07) 43.DEL Z A( 4.28973D-09) 44.       ( 0.0          ) 45.       ( 0.0          )
45.       ( 0.0         ) 47.       ( 0.0         ) 48.       ( 0.0         ) 49.       ( 0.0          ) 50.       ( 0.0          )
51.       ( 0.0         ) 52.       ( 0.0         ) 53.       ( 0.0         ) 54.       ( 0.0          ) 55.       ( 0.0          )
56.       ( 0.0         ) 57.       ( 0.0         ) 58.       ( 0.0         ) 59.       ( 0.0          ) 60.       ( 0.0          )
61.       ( 0.0         ) 62.       ( 0.0         ) 63.       ( 0.0         ) 64.       ( 0.0          ) 65.       ( 0.0          )
66.       ( 0.0         ) 67.       ( 0.0         ) 68.       ( 0.0         ) 69.       ( 0.0          ) 70.       ( 0.0          )
```

THRUST SWITCHING TIMES (DAYS) 0.0 OFF 189.220 VISIT 199.220 ON 368.000 OFF

ELECTRIC PROPULSION PARAMETERS

POWER	EFFICIENCY	PROP TIME	J	PROP TIME RATIO	AVE ACCEL
18175.6839354431	0.0000000045	0.0	0.0	0.0	0.0001000000

MASS COMPONENT BREAKDOWN

INITIAL	PROPULSION	PROPELLANT	TANKAGE	STRUCTURE	PAYLOAD
1634.7360602603	0.0	0.0	0.0	0.0	1634.7360602603

SWITCH-COUNT HISTORY ALL 5

0 THRUST COMPUTE STEPS, 52 COAST COMPUTE STEPS

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE	COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992	3.4		0.0	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0
4	82.559	93.1	MIN	0.898	54.6		0.23		-8.17D 04	*****	******	*****	0.0		90.0
5	179.513	200.2		1.016	77.6	MAX	0.47		-9.03D 04	*****	******	*****	0.0		90.0
4	189.220	209.3		1.032	79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
0	189.220	209.3		1.032	79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
4	199.220	218.3		1.047	82.5		0.45	OFF	-9.27D 04	*****	******	*****	0.0		90.0
4	267.702	275.6	MAX	1.102	106.2		0.29		-9.72D 04	*****	******	*****	0.0		90.0
4	368.000	362.8		0.993	101.8		0.00	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0

C-4

CASE 1

MISSION SCHEDULE

MARCH 6, 1985 1.2200000000D 01 G.M.T.
2446131.0000 00 JULIAN DATE — DEPART EARTH

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-9.6222210D-01	2.4221234D-01	0.0	-2.6045355D-01	-9.7355492D-01	0.0	9.9223898D-01	0.0	165.871
S/C	-9.6222210D-01	2.4221234D-01	0.0	-1.4812547D-01	-9.9515375D-01	-1.7689232D-03	9.9223898D-01	0.0	165.871

SEPTEMBR 11, 1985 1.7280000000D 01 G.M.T.
2446320.2200 00 JULIAN DATE — PASS GIACOB-ZIN(1985) AT 20.605 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	9.9607285D-01	2.6927994D-01	8.9095593D-04	-2.1743291D-01	1.0709149D 00	-6.7805209D-01	1.0318302D 00	0.049	15.128
S/C	9.9607279D-01	2.6927973D-01	8.9096022D-04	-1.6510441D-01	9.5271901D-01	1.5611264D-03	1.0318301D 00	0.049	15.128

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND GIACOB-ZIN(1985) IS 209.2569 DEGREES.

MARCH 9, 1986 1.2000000000D 01 G.M.T.
2446499.0000 00 JULIAN DATE — PASS EARTH AT 3.556 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	-9.7346085D-01	1.9576794D-01	0.0	-2.1349335D-01	-9.8418468D-01	0.0	9.9295071D-01	0.0	168.629
S/C	-9.7346107D-01	1.9579863D-01	5.6644505D-08	-9.5434335D-02	-1.0018430D 00	-1.8355305D-03	9.9295698D-01	0.000	168.627

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND EARTH IS 2.7583 DEGREES.

CASE 1 (CONVERGED)

PERFORMANCE SUMMARY

EARTH TO EARTH FLYBY

WITH VISITATION OF GIACOB-ZIN(1985)

LAUNCH VEHICLE IS ATLAS(SLV3X)/CENTAUR (COEFFICIENTS = 77360.1300 3652.7918 1653.7180)

LD = MAR 6, 1985, 12.0000 HOURS GMT
JULIAN DATE 46131.0000

AD = MAR 9, 1986, 12.0000 HOURS GMT
JULIAN DATE 46499.0000

FLIGHT TIME = 368.0000 DAYS.

ELECTRIC PROPULSION SYSTEM PARAMETERS

ALPHA A (KG/KW)	ALPHA T (KG/KW)	TANKAGE FACTOR	STRUCTURE FACTOR	EFFICIENCY COEFFICIENTS B	D (KM/SEC)	E
0.0	0.0	0.0300	0.0	0.76300	13.00000	0.0

ELECTRIC PROPULSION SYSTEM MASS SUMMARY (KG)

INITIAL	POWER PLANT	PROPELLANT	TANKAGE	STRUCTURE	NET MASS
1634.7361	0.0	0.0	0.0	0.0	1634.7361

ELECTRIC PROPULSION SYSTEM PERFORMANCE SUMMARY

P(1 AU) (KW)	P(HSKP) (KW)	P(TARG) (KW)	THR(1 AU) (N)	ACC(1 AU) (M/SEC**2)	ISP (SEC)	EFFIC	CHAR DEG (DAYS)
18175.6839	0.0	18339.2277	0.163474	1.0000000D-04	0.102	0.00000	1.00000000D 30

EXTREME TRAJECTORY AND PERFORMANCE CONDITIONS

MAX DIST (AU)	MIN DIST (AU)	MAX POWER (KW)	MAX THRUST (N)	BURN TIME (DAYS)	DEGRD TIME (DAYS)	TRAV ANG (DEG)
1.1019581	0.8982011	0.0	0.0	0.0	0.0	362.75652

DEPARTURE AND ARRIVAL CONDITIONS

DEP DECL (DEG)	PARK INC (DEG)	DEP VINF (M/SEC)	C3 (KM**2/SEC**2)	ARR VINF (M/SEC)	C4 (KM**2/SEC**2)
-5.1246	28.5000	3407.29049	11.609629	3555.93883	12.644701

SWINGBY CONTINUATION ANALYSIS

```
THIS CASE IS CONVERGED.

    11 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND   4 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

                                          EARTH        SWINGBY CONTINUATION TO       EARTH

PASS DIST (RADII)  SPEED (M/SEC)  INCLIN (DEG)  NODE (DEG)  ARG PER (DEG)   LEG TIME (DAYS)  MISSION TIME (DAYS)  ARR VINF (M/SEC)
      60.0441         3837.49       162.1881      185.7729     108.232         527.95             895.95              3557.35

ARRIVAL    VOO =  1.18059057D-01 -1.76583002D-02 -1.88553052D-03      MAG =  1.19387235D-01    (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO =  1.14058254D-01 -3.52707653D-02  5.00585992D-07      MAG =  1.19387242D-01    (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL    VOO =  9.88875047D-01 -1.47907774D-01 -1.57934010D-02      MAG =  1.00000000D 00    (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO =  9.55363839D-01 -2.95431779D-01  4.19296052D-05      MAG =  1.00000000D 00    (ECLIPTIC REFERENCE SYSTEM)

HELIOCENTRIC APPROACH ANGLE = 177.0.  DEPART ANGLE = 174.2.  BEND ANGLE =   8.7 DEGREES.
SWINGBY INCLINATION W.R.T. ECLIPTIC =  -6.0 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED =      0.0 METERS/SECOND.   BEND ANGLE =   8.7 DEGREES.  (PLANETOCENTRIC)

-------------------------------------------------------------------------------------------------------------------------------

POWERED SWINGBY ANALYSIS ONLY. FOR FIXED SWINGBY LEG FLIGHT TIME   127.0 DAYS.

THIS CASE IS CONVERGED.

     5 TRAJECTORIES WITHOUT PARTIAL DERIVATIVES AND   2 TRAJECTORIES WITH PARTIAL DERIVATIVES REQUIRED FOR THIS CASE.

ARRIVAL    VOO =  1.05096419D-01 -5.67395634D-02 -4.65529660D-07      MAG =  1.19434649D-01    (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO =  8.32614018D-02  8.24040653D-02 -1.79817708D-02      MAG =  1.18516814D-01    (ECLIPTIC REFERENCE SYSTEM)

ARRIVAL    VOO =  8.79949161D-01 -4.75067862D-01 -3.89777727D-05      MAG =  1.00000000D 00    (ECLIPTIC REFERENCE SYSTEM)
DEPARTURE VOO =  7.02528184D-01  6.95294303D-01 -1.51723374D-01      MAG =  1.00000000D 00    (ECLIPTIC REFERENCE SYSTEM)

HELIOCENTRIC APPROACH ANGLE =   5.7.  DEPART ANGLE =  78.9.  BEND ANGLE =  73.3 DEGREES.
SWINGEY INCLINATION W.R.T. ECLIPTIC =   9.1 DEGREES.

POWERED SWINGBY INCREMENTAL SPEED =    -13.7 METERS/SECOND.   BEND ANGLE =  73.3 DEGREES.  (PLANETOCENTRIC)

                                          EARTH        SWINGBY CONTINUATION TO  BORRELLY(1987)

PASS DIST (RADII)  SPEED (M/SEC)  INCLIN (DEG)  NODE (DEG)  ARG PER (DEG)   LEG TIME (DAYS)  MISSION TIME (DAYS)  ARR VINF (M/SEC)
       3.3636         7057.96        15.9836       15.8632     263.592         127.00            1022.95             17349.74

-------------------------------------------------------------------------------------------------------------------------------
```

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO EARTH

FOR SOLUTION HAVING 60.04 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
R1 REL	R2 REL	R3 REL	V1 REL	V2 REL	V3 REL	RMAG REL	VMAG REL
S/C NUC MAG	S/C TOT MAG	GEO NUC MAG	GEO TOT MAG	ANG(V,R)	ANG(V,XY)		
R1 REL ECL	R2 REL ECL	R3 REL ECL	V1 REL ECL	V2 REL ECL	V3 REL ECL	RMAG ECL	VMAG ECL

EARTH — START OF TRAJECTORY SEGMENT 3, THRUST OFF

3.68000000D 02	1.03625958D 00	1.09300439D-01	2.86571131D-05	1.79999991D 02	3.48627474D 02	9.92956978D-01	3.62756518D 02
-9.73461071D-01	1.95798630D-01	5.66445051D-08	-9.94351039D-02	-1.01945546D 00	5.00585992D-07	1.00000000D 00	1.70147744D-02
4.42397226D-02	5.72647197D-01	9.08642764D-04	-4.71642417D-01	9.01774272D-02	-1.06553100D-05	1.00000000D 00	-2.55037591D-02
0.0	0.0	0.0	9.61297040D 01	2.82703697D 02	1.01185946D 00	1.00899794D 00	-3.56615874D 04
9.06712656D-02	-8.30450619D 01	8.30450707D 01	3.26851127D-06	1.68627465D 02	-5.80167143D 00	1.02429331D 00	0.0
9.37043785D 02	-4.49482319D 03	8.47396132D 00	-3.53765537D 00	3.60129800D-01	1.49099120D-05	4.59146582D 03	3.55593905D 00
-4.52697209D 00	-7.58024821D 00	-1.00000000D 30	-1.00000000D 30	1.74187371D 02	2.40238942D-04		
-3.24620058D 01	4.59134325D 03	8.47396132D 00	3.39721558D 00	-1.05053740D 00	1.49099120D-05	4.59146582D 03	3.55593905D 00

EARTH — END OF TRAJECTORY, THRUST OFF

8.95945897D 02	1.03625958D 00	1.09300439D-01	2.86571131D-05	1.79999991D 02	1.45934513D 02	1.01205077D 00	8.80063558D 02
8.38380643D-01	-5.66890347D-01	1.40795398D-07	6.49008911D-01	7.68090940D-01	-4.65529660D-07	1.00000000D 00	1.66065959D-02
-5.76592725D-01	-7.09802000D-01	-8.22036755D-04	8.09433294D-01	-5.48973269D-01	-5.16342137D-04	1.00000000D 00	-2.55037591D-02
0.0	0.0	0.0	7.94284059D 01	2.60568839D 02	1.01186946D 00	9.84792437D-01	-3.58057058D 04
-5.15304272D-02	-9.50224599D 01	9.50224579D 01	7.97092623D-06	-3.40654957D 01	6.13109852D 00	1.00557260D 00	0.0
3.76962632D 01	-7.02304520D 00	2.10628507D 01	3.53975135D 00	3.53421754D-01	-1.38657621D-05	4.37490012D 01	3.55735106D 00
-1.31587261D 01	-1.76437918D 01	-1.00000000D 30	-1.00000000D 30	5.70172444D 00	-2.23325187D-04		
2.72936130D 01	-2.69330673D 01	2.10628507D 01	3.13028809D 00	-1.68998317D 00	-1.38657621D-05	4.37490012D 01	3.55735106D 00

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THRUST ANGLES THETA	THRUST ANGLES PHI	INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		3.4		0.0	OFF	-8.85D 04	*****	******	*****	0.0	ON	90.0
4	82.559	93.1	MIN	0.898		54.6		0.23		-8.19D 04	*****	******	*****	0.0		90.0
5	179.513	200.2		1.016		77.6	MAX	0.47		-9.03D 04	*****	******	*****	0.0		90.0
4	189.220	209.3		1.032		79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
0	189.220	209.3		1.032		79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
4	199.220	218.3		1.047		82.5		0.45	OFF	-9.27D 04	*****	******	*****	0.0		90.0
4	267.702	275.6	MAX	1.102		106.2		0.29		-9.72D 04	*****	******	*****	0.0		90.0
4	368.000	362.8		0.993		101.8		0.00	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0
0	368.000	362.8		0.993		101.8		0.00	OFF	-3.57D 04	*****	******	*****	0.0		90.0
4	368.005	362.8		0.993		84.2	MIN	0.00		-3.57D 04	*****	******	*****	0.0		90.0
4	434.075	436.2	MIN	0.923		54.6		0.17		-3.52D 04	*****	******	*****	0.0		90.0
5	521.214	530.2		1.032		83.4	MAX	0.34		-3.50D 04	*****	******	*****	0.0		90.0
4	626.726	616.2	MAX	1.150		169.8		0.16		-3.59D 04	*****	******	*****	0.0		90.0
9	632.049	620.2		1.149		179.5	MIN	0.16		-3.59D 04	*****	******	*****	0.0		90.0
7	632.345	620.4		1.149	MAX	180.0		0.16		-3.59D 04	*****	******	*****	0.0		90.0
5	742.568	712.1		1.012		82.8	MAX	0.35		-3.53D 04	*****	******	*****	0.0		90.0
4	819.377	796.2	MIN	0.923		57.9		0.20		-3.52D 04	*****	******	*****	0.0		90.0
3	895.946	880.1		1.012		92.6	MIN	0.00		-3.53D 04	*****	******	*****	0.0		90.0
4	895.946	880.1		1.012		149.5		0.00	OFF	-3.58D 04	*****	******	*****	0.0	ON	90.0

AUGUST 19, 1987 1.07015183D 01 G.M.T.
2447026.946D 00 JULIAN DATE PASS EARTH AT 3.557 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	8.38380460D-01	-5.66890170D-01	0.0	5.43912190D-01	8.24830500D-01	0.0	1.01205050 00	0.0	-34.065
S/C	8.38380640D-01	-5.66890350D-01	1.40795400D-07	6.49008910D-01	7.68090940D-01	-4.65529660-07	1.01205080 00	0.000	-34.065

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND EARTH IS 160.0636 DEGREES.

DETAILED PRINT OF POST-SWINGBY TRAJECTORY SEGMENT TO BORRELLY(1987)

FOR SOLUTION HAVING 3.36 PASSAGE DISTANCE

TIME	SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	NODE	ARG POS	RMAG	TRAVEL
R1	R2	R3	V1	V2	V3	MASS RATIO	THRUST ACC
L1	L2	L3	L4	L5	L6	L7	HAM
LG	LC	LPHI	CONE	CLOCK	HMAG	POWER FNCT	SWITCH FNCT
PSI	THETA	PHI	LATITUDE	LONGITUDE	FLT PTH ANGLE	VMAG	PROP TIME
R1 REL	R2 REL	R3 REL	V1 REL	V2 REL	V3 REL	RMAG REL	VMAG REL
S/C NUC MAG	S/C TOT MAG	GEO NUC MAG	GEO TOT MAG	ANG(V,R)	ANG(V,XY)		
R1 REL ECL	R2 REL ECL	R3 REL ECL	V1 REL ECL	V2 REL ECL	V3 REL ECL	RMAG ECL	VMAG ECL

EARTH

START OF TRAJECTORY SEGMENT 4, THRUST OFF

8.959458970 02	1.316758960 00	2.31624927D-01	9.34109222D-01	1.45934993D 02	1.79999511D 02	1.01205077D 00	8.80063558D 02
8.38380643D-01	-5.66890347D-01	1.40795398D-07	6.27173894D-01	9.07234569D-01	-1.79817708D-02	1.00000000D 00	1.66065959D-02
-5.76592725D-01	-7.09802000D-01	-8.22036755D-04	8.09433294D-01	-5.48973269D-01	-5.16342137D-04	1.00000000D 00	6.85470793D-02
0.0	0.0	0.0	7.94284059D 01	2.60568839D 02	1.11629508D 00	9.84792437D-01	-3.58057058D 04
-9.82025299D-01	-9.50231976D 01	9.50224579D 01	7.97092523D-06	-3.40654957D 01	5.90543552D-01	1.10306165D 00	0.0
-1.69367987D 08	-6.70264746D 07	7.21319315D 07	2.63030952D 01	5.91323267D 00	5.18989117D 00	1.95910895D 08	2.74545826D 01
1.73856513D 01	1.69804738D 01	1.73856509D 01	1.69804738D 01	1.66528869D 01	1.08965033D 01		
-1.19806972D 08	-6.18246515D 07	1.42144577D 08	2.60083123D 01	3.05278047D 00	-8.24635270D 00	1.95910895D 08	2.74545826D 01

BORRELLY(1987)

END OF TRAJECTORY, THRUST OFF

1.02294590D 03	1.31675896D 00	2.31624927D-01	9.34109222D-01	1.45934993D 02	2.87810226D 02	1.35864643D 00	9.87874273D 02
3.80201236D-01	1.30419417D 00	-2.10878993D-02	-7.34535522D-01	4.16015951D-01	1.08930260D-03	1.00000000D 00	1.09773500D-02
8.11785347D-01	-4.19648936D-01	4.26549064D-03	2.10373153D-01	4.35492117D-01	5.25235184D-03	1.00000000D 00	6.85470793D-02
0.0	0.0	0.0	1.03022842D 02	2.62522979D 02	1.11629508D 00	6.46819844D-01	-3.89521325D 04
3.76840308D-01	-1.01086943D 02	1.01086701D 02	-8.89338181D-01	7.37474369D 01	1.32703596D 01	8.44164020D-01	0.0
4.86518811D 00	-9.59694915D 00	-2.09227858D 00	4.70047212D 00	-1.13557788D 01	-1.22460387D 01	1.09612553D 01	1.73497439D 01
-1.70193101D 01	-2.00098098D 01	1.48530167D 01	1.42706208D 01	7.42807077D 01	-4.48969591D 01		
8.27254589D 00	2.54795529D 00	-6.72473244D 00	4.72217933D 00	3.25534561D 00	-1.63742896D 01	1.09612553D 01	1.73497439D 01

CASE 1

EXTREMUM POINTS OF SELECTED FUNCTIONS

I	TIME	ECLIPTIC LONGITUDE		SOLAR DISTANCE		COMMUNICATION ANGLE		COMMUNICATION DISTANCE		SWITCH FUNCTION	THRUST ANGLES PSI	THETA	PHI	INPUT POWER		ARRAY ANGLE
0	0.0	0.0		0.992		3.4		0.0	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0
4	82.559	93.1	MIN	0.898		54.6		0.23		-8.19D 04	*****	******	*****	0.0		90.0
5	179.513	200.2		1.016		77.6	MAX	0.47		-9.03D 04	*****	******	*****	0.0		90.0
4	189.220	209.3		1.032		79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
0	189.220	209.3		1.032		79.9		0.46	OFF	-9.15D 04	*****	******	*****	0.0		90.0
4	199.220	218.3		1.047		82.5		0.45	OFF	-9.27D 04	*****	******	*****	0.0		90.0
4	267.702	275.6	MAX	1.102		106.2		0.29		-9.72D 04	*****	******	*****	0.0		90.0
4	368.000	362.8		0.993		101.6		0.00	OFF	-8.35D 04	*****	******	*****	0.0	ON	90.0
0	368.000	362.8		0.993		101.8		0.00	OFF	-3.57D 04	*****	******	*****	0.0		90.0
4	368.005	362.8		0.993		84.2	MIN	0.00		-3.57D 04	*****	******	*****	0.0		90.0
4	434.075	436.2	MIN	0.923		54.6		0.17		-3.52D 04	*****	******	*****	0.0		90.0
5	521.214	530.2		1.032		83.4	MAX	0.34		-3.50D 04	*****	******	*****	0.0		90.0
4	626.726	616.2	MAX	1.150		169.8		0.16		-3.59D 04	*****	******	*****	0.0		90.0
9	632.049	620.2		1.149		179.5	MIN	0.16		-3.59D 04	*****	******	*****	0.0		90.0
7	632.345	620.4		1.149	MAX	160.0		0.16		-3.59D 04	*****	******	*****	0.0		90.0
5	742.568	712.1		1.012		82.8	MAX	0.35		-3.59D 04	*****	******	*****	0.0		90.0
4	819.377	796.2	MIN	0.923		57.9		0.20		-3.52D 04	*****	******	*****	0.0		90.0
3	895.946	880.1		1.012		92.6	MIN	0.00		-3.58D 04	*****	******	*****	0.0		90.0
4	895.946	880.1		1.012		149.5		0.00	OFF	-3.59D 04	*****	******	*****	0.0	ON	90.0
0	895.946	880.1		1.012		149.5		0.00	OFF	-3.58D 04	*****	******	*****	0.0		90.0
7	895.946	880.1		1.012		151.1	MIN	0.00		-3.53D 04	*****	******	*****	0.0		90.0
8	963.191	945.8		1.150	MAX	173.7		0.16		-3.59D 04	*****	******	*****	0.0		90.0
4	1022.946	987.9		1.359		125.6		0.53	OFF	-3.93D 04	*****	******	*****	0.0	ON	90.0

DECEMBER 24, 1987 1.07015188D 01 G.M.T.
2447153.946D 00 JULIAN DATE

PASS BORRELLY(1987) AT 17.350 KM/SEC

	X	Y	Z	XDOT	YDOT	ZDOT	RADIUS	LAT.	LONG.
PLANET	3.80201180D-01	1.30419420D 00	-2.10878540D-02	-8.93373160D-01	3.05720850D-01	5.50840370D-01	1.35864640D 00	-0.889	73.747
S/C	3.80201240D-01	1.30419420D 00	-2.10878990D-02	-7.34535520D-01	4.16015950D-01	1.08930260D-03	1.35864640D 00	-0.889	73.747

TWO-BODY TRANSFER ANGLE BETWEEN EARTH AND BORRELLY(1987) IS 267.8768 DEGREES.

V. REFERENCES

[1] Pontryagin, L.S., et al, The Mathematical Theory of Optimal Processes, Interscience Publishers, New York, 1962.

[2] "Launch Vehicles Estimating Factors," NASA Office of Space Science, Jan. 1973.

[3] Pines, S. and Fang, T.C., "A Uniform Closed Solution of the Variational Equations for Optimal Trajectories During Coast," presented at the Colloquium on Advanced Problems and Methods for Space Flight Optimization, Liege, Belgium, June 1967.

[4] Robbins, H.M., "An Analytical Study of the Impulsive Approximation," AIAA Journal, Vol. 4, No. 8, pp. 1417-1423, 1966.

[5] P. Gunther, "Asymptotically Optimum Two-Impulse Transfer from Lunar Orbit," AIAA Journal, Vol. 4, No. 2, pp. 346-349, February 1966.

[6] Jerry L. Horsewood and F.I. Mann, "The Optimization of Low Thrust Heliocentric Trajectories with Large Launch Asymptote Declinations," AIAA Paper No. 74-803, Presented at the AIAA Mechanics and Control of Flight Conference, Anaheim, California, August 5-9, 1974.

[7] F.I. Mann and J.L. Horsewood, "Selected Solar Electric Propulsion and Ballistic Missions Studies," NASA CR-132753, January 1973.

[8] J.L. Horsewood, F.I. Mann and K.B. Brice, "The Generation and Interpretation of Electric Propulsion Mission Analysis Data," AMA, Inc. Report No. 73-38, August 1973.

[9] Fimple, W.R. and Edelbaum, T.N., "Applications of SNAP-50 Class Powerplants to Selected Unmanned Electric Propulsion Missions," AIAA Paper 64-494, 1964.

[10] Breakwell, J.V. and Rauch, H.E., "Asymptotic Matching in Power Limited Interplanetary Transfers," AAS Paper 66-114, 1966.

[11] Pines, S., Jazwinski, A.H., and Mann, F.I., "Low-Thrust Interplanetary Trajectory Open Loop Error Analysis," AMA, Inc. Report No. 71-9, February 1971.

[12] Horsewood, Jerry L., "A Guide to the Use of HILTOP, A Space Trajectory Optimization Computer Program," AMA, Inc. Report No. 73-30, June 1973.